Enhancing the competitiveness of research universities:
3 essays on the chances and challenges of new steering approaches in science

Dissertation

submitted to the

Faculty of Business, Economics and Informatics

of the University of Zurich

to obtain the degree of

Doktor der Wirtschaftswissenschaften, Dr. oec.

(corresponds to Doctor of Philosophy, PhD)

presented by

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approved in April 2016 at the request of

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The Faculty of Business, Economics and Informatics of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

Zurich, 06.04.2016

Chairman of the Doctoral Board: Prof. Dr. Steven Ongena

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Acknowledgements

This dissertation is the result of over four years of fascinating research and brings together innumerable insights I gathered during this period. Among the many lessons learned, the importance of the people that contributed to it is certainly the most fundamental. Their assistance proved essential to the realization of this extensive project, and I would like to express my gratitude for their support.

First of all, a very heartfelt thank you goes to my supervisor Andrea Schenker-Wicki, who gave me the opportunity to write my dissertation and was always ready to help me whenever I needed it. I am enormously grateful to her for sharing her passion for higher education management and policy with me, for letting me be part of so many fascinating projects and activities, and for believing in my abilities. Her insightful comments and her steady encouragement considerably contributed to the completion of this work. I would also like to sincerely thank Egon Franck for accepting to be my co-supervisor and for always being very supportive despite his many commitments. I deeply appreciated his friendliness and the interest he showed in my research.

I owe an enormous debt of gratitude to Susanne Suter, who encouraged me to start this journey in the first place and helped me to find such a great place to pursue my research. A special thank you also goes to my former colleagues at the Secretariat of the Swiss Science and Innovation Council for the many interesting discussions and enjoyable moments we had in Bern, which were an important source of motivation and inspiration for me.

I wish to thank Benedetto Lepori for taking part in the project that resulted in my second dissertation paper. I am deeply grateful to him for sharing his profound knowledge with me, for his precious feedback on my work, and for the many stimulating ideas he gave me during our discussions of the project.

Then I wish to thank all of my former colleagues at the Chair of Performance Management: Matthias Inauen and Stephan Schembera, for supporting me at the very beginning of my dissertation; Maria Olivares, for her advice on the first dissertation paper and for introducing me to Data Envelopment Analysis; Lukas Schönenberger, for his suggestions and his many initiatives to bring the chair together; Katherine Caves, for her precious editorial help; Xinhua Wittman, for sharing her expertise and her exciting international projects with us; Tomas Hermida, for his accurate and very reliable administrative support; and Adina Bialas and Maria Franco, for the kindness they always showed. A very special thank you goes to Mathias Beck, who was always friendly and helpful, providing precious advice especially at the end of my dissertation.

I am deeply thankful to Christian Schwarzenegger, Stefanie Kaiser, and my former colleagues at the Office of the Vice President for Law and Economics, who made my daily work so rewarding and supported me in my professional development. I am also thankful to the whole team of the Executive MBA program and the people of the Chair in Human Resource Management for the many chats we had and for making my days at the Plattenstrasse so pleasant. A special thank you goes to Sabrina Pfister and Mehtap Neves, who shared the office with me and whose friendliness contributed to a wonderful working atmosphere.

Finally, I owe an enormous debt of gratitude to my family and friends. Without the dedicated support of my parents, Brigitte and Jürg Nigsch, I would not be where I am today. I cannot thank them enough for their unconditional love and for always being there for me. I am enormously grateful to my sister Claudia and my brother Andrea, for sharing so much with me and always helping me whenever I need it. A special thank you is reserved for my nephew Ranvir, as he cheers me up each time he is around. Lastly, my deepest thanks go to Ilya, Olivia, Raphaël, and Andrea, whose affection has always given me strength and filled me with joy.

Zurich, January 2016

Stefano Nigsch

Framework paper

1. University growth, competitiveness, and reforms

Today, universities represent fundamental institutions, one could say constitutive elements, of industrialized countries all over the world. In the last century, they have experienced an unprecedented growth and major organizational changes, due, essentially, to the rapid technological progress and the “massification” of higher education (see e.g. Teichler 1998). Since the end of World War II, higher education has evolved from an elite system, where only a very small percentage of the population had access to universities, to a universal system in which more than 50 percent of young adults attend a form of tertiary education (Trow 2007). The growing demand for higher education and the increasing role of knowledge in people’s everyday life have made universities an integral part of societies, overcoming once and for all their image as “ivory towers” inhabited by few scholars only weakly connected to their surrounding communities (Barry et al. 2001).

The importance of universities is not confined to education and training but comprises their role as research institutions and their “third mission”, i.e. their contribution to economic development and social welfare (Martin 2012). Technology-based economies rely on scientific progress and research at the technological frontier to remain innovative and competitive, and to secure the basis for long-lasting growth (see e.g. Stephan 2012). Analytic frameworks like the National Innovation System approach (Freeman 1995, Lundvall 1992, Nelson 1993), the Triple Helix approach (Etzkowitz and Leydesdorff 2000), and the Mode 2 of science approach (Gibbson et al. 1994) thus include universities as key elements of successful economies. Research universities train highly skilled employees, conduct a large part of basic and applied research, secure new generations of scholars, and take active steps towards collaboration with industry and technology transfer (Rosenberg & Nelson 1994). They have therefore become a decisive factor influencing both the competitiveness of an economy and the attractiveness of a country or a region for international high-technology companies.

However, the growing costs of universities caused by their exceptional growth has led to funding problems, especially in countries where universities are strongly dependent on public resources (Trow 1999). Moreover, the increasing international competition among research systems has called for a more effective allocation of public funds (Bonaccorsi 2007, Jacobs and van der Ploeg 2006). For these reasons, most industrialized countries and many developing ones have implemented reforms to increase the efficiency of their higher education and research system and its responsiveness to external demands. As in other public domains, such as health or transport, these reforms have relied on the New Public Management discourse and have introduced new steering approaches, i.e. external instruments and institutional arrangements that shape organizational governance and academic behaviors within higher education institutions (Ferlie et al. 2008).

These new steering approaches are based on two interrelated principles, autonomy and competition, which have both been shown to significantly influence the performance of research universities (Aghion et al. 2010). First, following the idea that self-organization leads to better results, many governments have granted universities more autonomy in strategic, organizational, financial, and personnel matters (Estermann and Nokkala 2009). At the same time, they have introduced new accountability mechanisms in order to ensure the quality of university services and the proper use of public funds (see e.g. Paradeise et al. 2009, Whitley and Glaeser 2007). These developments have led to the rise of "new managerialism" approaches in higher education (Deem & Brehony, 2005), the professionalization of management functions within universities, and an increasing focus on institutional performativity (Ollsen & Peters, 2005).

Second, several reforms have been implemented with the aim of increasing competition for funds among universities, in the belief that market-mechanisms lead to a more efficient allocation of resources (van der Ploeg and Veugelers 2008). In many countries, funding has been linked to performance indicators (see e.g. Butler 2010, Hicks 2012). Similarly, the share of institutional funding, i.e. state funding allocated directly to universities, has been reduced, while the importance of competitive project funding and funding from industry has increased (Lepori et al. 2007, Perkmann et al. 2013). The growing focus on the returns of research spending has also led many governments to expand the share of research oriented towards societal, economic, and political needs at the expenses of free academic research (see e.g. Morris 2000).

One of the culminating goals of all these reforms is to create – and promote – a new type of higher education institutions, which has been called the “emerging global model” of research universities (Mohram et. al 2008). These universities are characterized by a strong orientation on research and by a high degree of internationalization. They are engaged in a worldwide competition for the best international students, high-profile researchers, and partners both from within the academic world, i.e. other universities and research institutions, and from outside academia, such as high-technology firms, government and private non-profit-organizations, and foundations (Marginson 2006). Competition thereby strongly builds on the reputation of universities, which is directly associated to their research performance (Horta 2009). Thus, increasing the competitiveness of universities essentially means giving them the means to conduct high quality education and research, and providing an adequate environment and the right incentives for them to fully unfold their potential.

2. Previous and ongoing research

The many reforms implemented may affect the future development of universities in various ways. A better understanding of the chances and challenges of the new steering approaches and their intended and unintended consequences is crucial for the future design of policies, the governance of higher education and research systems, and the management of universities. These topics have consequently received a great amount of attention in academia. They have been analyzed from very different perspectives, including historical, sociological, educational, policy, management, and economic approaches. Their relevance is reflected in the growth of this highly interdisciplinary field of study, the creation of specialized journals, and the establishment of thematic associations and regular conferences.

The literature on the reforms in higher education and research is so broad and diverse that a full review would go far beyond the scope of this paper. Nevertheless, by focusing on the specific research objects rather than the disciplinary perspectives and methodologies, referring only to selected studies, and making no claim to completeness, one can identify six groups of contributions to the ongoing academic discourse. A first group of studies analyzes the implications of the reforms for the internal management and organization of universities. These studies focus on, among other things, how New Public Management approaches have been implemented in universities (Bleiklie 1998, Boden et al. 2006), how management models from industry and business can be applied to the higher education system (Buckland 2009), and whether such models truly increase the efficiency of universities (Schubert 2009). Other relevant topics are the emergence of professional management positions in universities (Blaschke et al. 2014) and the many accountability mechanisms introduced by the state (Whitley and Glaeser 2007).

A second group of studies focuses on the implications of current developments for teaching and learning at universities. The risk of a loss of quality due to the massification of higher education, increased administrative workload, and performance incentives exclusively oriented towards research (Mcinnis 2000) has made quality assurance in teaching and learning a highly relevant topic (Harvey and Newton 2004, Massaro 2010). Of particular interest are questions relating to the applicability of quality assurance models from business (Becket and Brookes 2008) and the changing expectations of society about the competences that students should acquire (Knight and Yorke 2003, Moore and Morton 2015). Moreover, specific educational reforms, such as the curricula changes introduced by the Bologna Process, have received substantial attention (Keeling 2006).

A third group of studies discusses the implications of the new steering approaches for research at individual level. The increasing reliance on project funding and the importance of performance indicators have been criticized for compromising scientific progress in the long run (Geuna 2001, Nedeva & Boden 2006). Many scholars have argued that quantitative measures for research output set problematic incentives that significantly affect the behavior of scientists (see e.g. Ringelhan et al. 2015 for an overview). Other studies have analyzed the impact of different types of funding on the research performance of individual scholars (see e.g. Arora and Gambardella 2005, Beaudry and Allaoui 2012), identifying features of funding schemes that are particularly well suited for science (Azoulay et al. 2011, Laudel & Glaeser 2014). Finally, the implications of the increasing reliance of public research on private funding has also attracted considerable attention in the literature (Gulbrandsen and Smeby 2005, Muscio et al. 2013).

A fourth group of contributions analyzes whole universities or university departments. Besides the paper of Aghion et al. (2010) on autonomy and competition, only a few studies have tried to assess whether competitive funding is positively associated with the research output of universities in terms of publications and citations (see e.g. Bolli and Somogyi 2011). Special attention has been given to the assessment of university performance and in particular to the validity and the limitations of university rankings, which regularly gain high visibility in public media (Hazelkorn 2015). Another stream of the literature has focused on productivity and efficiency issues, applying both parametric and non-parametric frontier analysis techniques to higher education institutions. Scholars have analyzed how university efficiency has evolved over time, how it varies across countries, and which conditions are associated with higher efficiency (for an overview see Nigsch and Schenker-Wicki 2015).

A fifth group of studies takes a broader perspectives and examines whole university and research systems in different countries. A small number of studies has assessed whether more competitive environments display higher scientific output (Auranen and Nieminen 2010), and have identified further elements affecting the success of research systems (Crespi and Geuna 2008). Special attention has also been given to the governance of university and research systems (see e.g. Braun 2008), coordination modes in science (Lepori 2011), and the relationship between the government, the scientific community, and intermediary organizations (Braun 1993, van der Meulen 1998). Moreover, scholars have described and discussed the overall changes in policies in several countries, such as trends in funding approaches and the emergence of new funding mechanisms (Lepori et al. 2007).

A final group of studies is not directly concerned with the reforms in higher education but rather with the general structural changes that accompany these processes. Several contributions have discussed the diversification of higher education, as reflected by the increasing diversity of the student population, the specialization of existing universities on specific profiles, and the emergence of new types of institutions (Fumasoli and Huisman 2013, Horta et al. 2008). Another growing stream of the literature investigates the interaction of universities and the business world, the advantages and disadvantages of common research projects with industry, academic entrepreneurship, and other related aspects (Geuna and Muscio 2009, Markman et al. 2004). Finally, several scholars have investigated the ongoing internationalization processes in science and, more specifically, the creation of a common European Research Area (Marginson 2006, Luukkonen and Nedeva 2010, Teichler 2004).

3. The contribution of this dissertation

Higher education systems are in continuous development and despite the fact that scholars have provided numerous valuable studies and contributions, many questions still remain to be answered. The present dissertation analyses selected aspects related to the new steering approaches in science, complementing several existing literature streams. It deals with questions relating to quality management and accountability, to the changing funding approaches in research, and to the overall governance of higher education systems. The three dissertation papers are connected by the common goal of identifying chances and challenges for the promotion of internationally successful research universities in the context of the recent reforms.

Given that the research field is highly multi-disciplinary, the dissertation draws on several approaches that comprehend, apart from the main management perspective, elements from economics and political science. Many previous studies have been qualitative and theoretical, and the aim of this contribution is to enrich the ongoing discussion by providing quantitative empirical evidence for assumptions about current developments and causal relationships, and by proposing new points of view. It thereby takes a strong international perspective, with all papers representing cross-national studies.

3.1 International accreditations and quality management systems

The first paper entitled "*Shaping performance: Do international accreditations and quality management really help?*" explores issues related to the introduction of business-like quality management systems in higher education and, in particular, of institutional accreditations, which have become increasingly popular both as internal quality development tools and as external quality assurance and accountability mechanisms (Stensaker 2011). Among business schools, international accreditations granted by prestigious organizations such as the Association to Advance Collegiate Schools of Business (AACSB) in the United States and the European Foundation for Management Development (EFMD), which grants EQUIS accreditation, have become common quality labels that considerably contribute to the reputation of an institution and its ability to attract international students and researchers.

While the process of acquiring an international accreditation may help business schools improve their organizational processes and their strategic planning, thus enhancing their performance (Zammuto 2008), it also involves high costs, the risk of increasing bureaucratization and a loss of flexibility and innovative capacity (Julian & Ofori-Dankwa, 2006). As in the case of other forms of quality management systems adapted from the business world, the overall effects of international accreditations are thus highly disputed in academia. Given that empirical evidence based on international quantitative studies is largely missing, the present study uses results from an international survey to assess how the acquisition of an AACSB or EQUIS accreditation and other quality management approaches are related to the reputation of business schools as measured by their research output.

The results point to a positive association of international accreditations with research performance. This association remains significant when one controls for the size of a business school, its expenditures per student, the availability of PhD programs, and the offer of Executive Education, which are all positively related to research performance. In contrast, other types of quality management systems do not exhibit any significant relationship to the performance measure used. These findings suggest that specific standards required by AACSB and EQUIS accreditations, such as having a coherent strategy and employing highly qualified personnel, may help business schools to enhance their performance and, consequently, their international reputation.

3.2 Distributional and productivity effects of competitive university funding

The second paper entitled "*Differentiation or convergence? The allocation of external funds among German and Swiss universities and its consequences for scientific production*" focuses on the increasing relevance of external project funding and the ways this tendency may affect universities. Competition for project funding is generally assumed to foster a concentration of resources in the best institutions, forcing universities to specialize in certain domains and thus promoting differentiation within the system (Abramo et al. 2012, Horta et al. 2008). At the same time, competition may also spur imitation and mutual learning, leading to a convergence of acquisition strategies among universities (see e.g. Jha and Lampel 2014). The question whether funding reforms truly foster differentiation among universities and a concentration of resources in the strongest research-oriented universities is highly relevant for policy makers.

Apart from this distributional effect, external project funding is also expected to increase the productivity of research, as it is usually granted to the best projects and the most talented researchers. However, this assumption does not necessarily apply to all types of external funds, the most common being research grants from national and international funding agencies, research contracts with government and industry, and contributions from foundations. These types of funding differ considerably in terms of their objectives and their requirements for applicants, and may lead to very different research outcomes. While several studies have analyzed the effects of single funding instruments at individual level (see e.g. Jacob & Lefgren 2011, Beaudry and Allaoui 2012), systematic analyses that account for the different types of external funding at university level are largely missing.

This paper contributes to the debate by analyzing five categories of external university funds in Germany and Switzerland, tracking their evolution over the last 10 years. In a first step, it assesses whether competition has led to a differentiation or rather a convergence of resource acquisition patterns. In a second step, it analyses how different types of funding are associated with scientific production in universities and universities of applied sciences. Empirical evidence supports the hypothesis of converge rather than differentiation, pointing to possibly unintended effects of the funding reforms. The results also suggest that association patterns of external funding and research performance vary considerably depending on the type of funding and the type of university. For instance, funds from national funding agencies prove to be positively related to the research performance of universities, while a negative association can be observed in the case of government contracts. In contrast, government contracts are positively associated with the research output of universities of applied sciences.

3.3 Identifying best practices among funding agencies in Europe

The third paper entitled "*Setting the stage for university research: Varying approaches and best practices among funding agencies in Europe*" investigates the consequences of the new steering approaches from a different perspective. Instead of analyzing universities, it focuses on funding agencies, which have become central players in science policy due to their task of allocating research funds competitively. In the course of the reforms, many governments have created new funding agencies, reformed existing ones, and expanded their budgets, often requiring an increase in thematic funding, i.e. funding directed towards previously defined research topics, at the expense of investigator-driven projects (Lepori et al. 2007). However, these developments have varied considerably across countries (Slipersaeter et al. 2007). As a result, funding agencies differ considerably in terms of their governance, their organization, and their funding schemes.

In the light of this great diversity, a highly relevant question is whether some models of funding agencies are better suited to fostering research at universities, and whether best practices can be identified. To date, several important conceptual and qualitative studies on funding agencies have been conducted (see e.g. Braun 1998, Benner and Sandström 2000). However, there is a lack of systematic comparative studies at the international level based on quantitative data and focusing on different types of agencies. To address the lack of comparative data, the paper develops a framework for categorizing funding agencies based on their specific funding profiles, and applies it to western European agencies.

In a second step, it investigates best practices for the promotion of university research at country level. The analysis identifies four causal combinations of agency characteristics and context factors associated with successful university research systems. With regard to the funding profile of agencies, a focus on investigator-driven project funding, on fellowships, or on large excellence programs seems promising, while a focus on thematic funding proves to be negatively related to research performance. With regard to the context factors, the results stress the importance of a high funding level of universities. These findings are not only important for national governments aiming at fostering their research universities, but may also prove relevant in view of the increasing role of international funding, since the European Framework Programs are still directed, to a large extent, towards thematic funding.

4. Overall conclusions and outlook

The three dissertation papers deal with several topics that are of interest to both university managers and policy-makers in charge of higher education and research. They draw on a rich literature on university reforms and aim at complementing it by providing empirical evidence based on quantitative international data. These quantitative approaches proved very useful, as they confirmed or rejected previous assumptions, allowed for more differentiated investigations, and brought some novel insights. The dissertation thus contributes to a better understanding of the reform processes underway and of their consequences for such multifaceted organizations as universities are. The various findings in the three papers entail suggestions that may help optimize both management and steering mechanisms, leading to a better resource allocation and – in the end – promoting strong research universities and enhancing their international competitiveness.

At the same time, the studies only represent first attempts to analyze the new steering approaches in science using quantitative methods, and can be further developed in several ways. Universities and higher education and research systems are extraordinary complex and diverse, and several simplifications had to be made in the course of the analyses. Specific aspects of the research topics may be analyzed separately and investigated more deeply. If more data are available in the future, the models may also be expanded to include additional observations or other variables. Due to the absence of viable alternatives, all three studies focus on traditional indicators for research performance, such as publication counts and rankings, being aware of the well-known limitations of these measures. While research performance remains the main factor affecting an institution’s reputation, analyses investigating other important tasks of universities, namely, teaching, knowledge transfer, and other contributions to society, are also of great interest.

Finally, as most other quantitative studies, the present analyses had to deal with several data issues. Not all data of interest could be gathered, and not all of it was available at the desired level of detail. Comparability problems also arose with internationally collected data and required serious efforts to be solved. Moreover, endogeneity represented a challenge that could not always be fully addressed with the information at hand. New data may thus help to optimize the models used, and to increase the robustness of the results. Given the relevance of university reforms and the high amount of public money invested in higher education and research, additional efforts to improve the quality of the data and its availability seem justified, and will open the doors to further exciting research.

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A Appendix: Papers included in the dissertation

A.1 Shaping performance: do international accreditations and quality management really help?*†

Abstract

In recent years, international accreditations have become an important form of quality management for business schools all over the world. However, given their high costs and the risk of increasing bureaucratization and control, accreditations remain highly disputed in academia. This paper uses quantitative data to assess whether accreditations can help a business school to foster its research performance and consequently its reputation. On the basis of an international survey, we analyze how being accredited by AACSB or EQUIS affects the institutions' position in the Top 1000 Business School Ranking of the Social Science Research Network. We find that international accreditations are positively related to research performance, while other approaches to quality management do not exhibit any significant relationship to ranking positions. These results point to the importance of specific standards required by AACSB and EQUIS accreditations such as having a coherent strategy and employing highly qualified personnel.

Keywords*:* higher education, business school, accreditation, quality management

* This paper has been written together with Andrea Schenker-Wicki.

† This paper has been published in: Nigsch, S., & Scheker-Wicki, A. (2013). Shaping performance: do international accreditations and quality management really help? *Journal of Higher Education Policy and Management, 35*(6), 668-681.

1. Introduction

The rise of quality management has been one of the most important transformations in higher education over the last 30 years. Two interrelated trends underlie this development. First, the emergence of "new managerialism" approaches in higher education (Deem and Brehony 2005) and the increasing focus on institutional performativity (Ollsen and Peters 2005) have led universities to implement internal quality management systems based on concepts and models from the business world. Second, many governments have started promoting external quality assurance in higher education as an accountability tool in order to ensure that public funds are properly invested (Massaro 2010, Harvey and Newton 2004).

In this context, institutional accreditations have become increasingly popular both as internal quality management approaches and as external quality assurance tools (Stensaker 2011). Among business schools in particular, voluntary accreditations by prestigious international organizations have spread worldwide. Today, being accredited by one of the two main agencies in this field, the Association to Advance Collegiate Schools of Business (AACSB) in the United States and the European Foundation for Management Development (EFMD, responsible for the EQUIS accreditation), considerably contributes to a business school's reputation. These "international" accreditations serve as a quality label and as a competitive advantage in the struggle for the best students and most outstanding researchers (Trapnell 2007, Urgel 2007).

However, the effect of accreditations remains highly disputed in academia. Many scholars see accreditations as a restriction on academic freedom, a fruitless bureaucratic burden, and an impediment to adaptation and innovation (Harvey 2004, Julian and Ofori-Dankwa 2006, Scheele 2004). Others view accreditations positively and stress their contributions to strategic planning and organizational effectiveness (Zammuto 2008, Lejeune and Vas 2009). In both cases, sound empirical evidence for the effect of accreditations is scant. Lejeune and Vas (2009) have analyzed the effect of EQUIS accreditations with quantitative survey data and found that accreditations positively influence organizational culture and effectiveness. However, their results were solely based on the perceptions of the business schools' deans and did not account for objective performance measures. Similarly, relatively few studies have provided empirical evidence for the positive or negative effects of other forms of quality management in higher education (Kleijnen et al. 2011). Notably scarce are quantitative international studies and contributions that focus on quality management in research, as opposed to merely teaching and learning (Harvey and Williams 2010).

In the present study, we address these gaps and use quantitative data to analyze whether international accreditations and other forms of quality management truly help a business school to improve its performance. Since research has become crucial for the overall reputation of higher education institutions, we focus on research performance as a dependent variable. Business schools doing quality research are able to attract leading scholars and high-performance students, enabling them to successfully compete at the international level. Moreover, research performance strongly affects the institutions' position in international university rankings (Buela-Casal 2007, Horta 2009). Despite being criticized for their methodology (see for example Toutkoushian et al. 2003), these rankings have a relevant social impact (Meredith 2004, Bowman and Bastedo 2011). Hence, we state our research question as follows: *How does the acquisition of an international accreditation affect a business school's reputation - measured as research performance - compared with other quality management approaches?*

Currently, the various activities related to quality management within higher education institutions require significant financial and personal resources (Stensaker 2003, Heriot et al. 2009). It is therefore important to assess how different forms of quality management may contribute to an institution's performance. Knowing which approaches accompany the best results may help governments and higher education managers to optimize their strategies for quality assurance and quality development, improving the reputation, productivity, and cost-efficiency of business schools and other higher education institutions.

2. Literature Review

Following Grant et al. (2004), we define quality management as all activities and processes deliberately carried out to design, evaluate and improve teaching, learning, research and administrative functions within higher education institutions. Quality management has always existed in academia (Newton 2007). However, with the diffusion of new public management approaches and the growing need for external accountability, many higher education institutions have begun to implement quality management systems based on concepts and models from the business world. Most of these systems follow the philosophy of Total Quality Management (Becket and Brookes 2008) and many of them adopt either the Malcolm Baldrige Criteria, the Excellence Model of the European Foundation for Quality Management (EFQM) or the ISO-9000 standards. Quality management systems based on concepts from business have the advantage of being easily accepted by external stakeholders (Brookes and Becket 2007). However, they do not always account for elements specific to higher education institutions, such as academic freedom (Thalner cit. in Houston 2008, p. 65).

The effect of quality management systems on the overall performance of higher education institutions remains disputed in academia (Tambi et al. 2008). According to Brennan and Shah (2000), the introduction of new quality management systems has been accompanied by a shift in power from the basic unit to the institutional level. Other studies have observed that new forms of quality management lead to higher bureaucratization (Kogan et al. 2000) and cause disproportionate costs compared to unclear effects (PA Consulting 2000). Lomas (2004) points out the issue of opportunity costs: the high amount of financial resources needed to implement and maintain a quality management system may be otherwise better invested. Among the positive effects of the new forms of quality management, scholars often mention increased transparency (Stensaker 2003).

Parallel to the diffusion of quality management systems based on concepts from business, accreditations have become an important way of ensuring the quality of higher education institutions (Stensaker 2011). The term “accreditation” describes a process by which an institution obtains the authorization to conduct educational programs recognized by the state or by another authority. This process makes use of a benchmarking method, refers to specific standards, and aims at a “yes or no” verdict (Haakstad 2001). Accreditations may focus on a specific educational program or an institution as a whole. In many European countries, higher education institutions need to be accredited by a national authority, while in the United States private agencies can grant accreditations. Some of these private agencies, such as AACSB and EFMD, focus on excellence rather than merely providing a “right to exist” (Schwarz and Westerheijden 2005, p. 2) and offer their services internationally. Achieving such a prestigious accreditation may thus increase a business school’s international reputation (Trapnell 2007, Urgel 2007).

Similarly to other forms of quality management, the true effects of accreditations are disputed in academia. For example, Harvey (2004, p. 207), based on a qualitative survey among academics and managers in Britain, the United States, and Canada, concluded that the accreditation process can be “a power struggle that impinges on academic freedom”, imposing extensive bureaucratic burdens in some cases. Accreditations may also limit innovation opportunities: Julian and Ofori-Dankwa (2006), who focus their analysis on AACSB accreditations, argue that the accreditation process hinders a business school’s capability to adapt to a “discontinuous” and “turbulent” environment characterized by technical innovations and increasing competition from corporate and virtual universities.

In contrast, Romero (2008) states that AACSB accreditations encourage flexibility and creativity. Although the author admits a “lack of published, hard and systematic data” on the effects of accreditation (Romero 2008, p. 246), he argues that accreditations provide incentives for strategic development, which may in turn improve performance (Miller and Cardinal 1994). Proitz et al. (2004), who analyzed EQUIS reports and recommendations, conclude that institutional accreditations foster diversity rather than standardization, and focus on improvement rather than control. The authors go as far as to question whether EQUIS standards are actually too weak to justify the amount of bureaucratization the accreditation process requires.

So far, only few studies have assessed the impact of accreditations using quantitative empirical data. Roller et al. (2003) conducted a survey among deans of North American business schools, and compared the perception of AACSB and other common accreditation agencies in the U.S. Among their results, they find that AACSB accreditation is particularly apt to promote excellence in research. On the basis of a survey among 31 deans and directors of EQUIS-accredited schools, Lejeune and Vas (2009) assert that accreditations improve a business school’s program development, its social openness and its ability to acquire resources, particularly qualified faculty and academic partners. In a later study, Lejeune (2011) presents a capability-based model to explain how international accreditations enable continuous improvement. He states that EQUIS accreditations foster three core-capabilities of business schools: strategizing, changing resources and activities, and branding.

3. Hypotheses

In line with Romero (2008) and Lejeune and Vas (2009), we expect that international accreditations will help business schools to improve their research performance. Although AACSB and EQUIS accreditations focus on teaching, they set clear standards that concern the strategic management of business schools, their organizational processes and the quality of faculty (AACSB 2012, EFMD 2012). Business schools applying for an accreditation need to take specific measures in order to meet these requirements and engage in a learning process that may increase quality and overall performance. We identified six ways in which accreditations can lead to a higher research performance.

1. Strategizing: Both AACSB and EQUIS require a clear mission statement that is known and shared by all business schools' faculty and collaborators. Developing a vision about the services they offer and the market they serve will improve the business schools' ability to compete successfully (Zammuto 2008). Moreover, mission statements should include a clear commitment to high quality research, which may lead business schools to promote research activities. Accredited institutions also need to develop clear strategies for reaching their goals and investing their resources (Lejeune 2011). According to the strategic management literature, having a good strategy is central to the success of an organization (see for example Pearce II et al. 1987, Mosakowski 1993). For instance, in the context of higher education, the presence of a research council responsible for an institution's long-term strategy positively affects research efficiency (Schubert 2009).

2. Effective management: EQUIS expects a business school to have "effective and integrated organization for the management of its activities" (EFMD 2012, p. 7). Similarly, "AACSB accreditation forces a business school to effectively manage its resources consistent with its mission" (Trapnell 2007, p. 69). Different management approaches may indeed have different effects on an institution's research activities. In a quantitative empirical study on the effects of new public management, Schubert (2009) finds that operative flexibility, resource control, the strength of deans and presidents, and the introduction of goal agreements are among the factors that positively influence research performance. Furthermore, effective management may release faculty members and scientific collaborators from administrative tasks, and create an environment that fosters good research.

3. Data collection: In order to meet the accreditation requirements, business schools must systematically collect data that reflects in detail the quality of teaching, learning, and research at their institution. In terms of organizational control theory, the use of such performance measures as a form of output control is particularly useful when task programmability is low, as in the case of research (Johnson 2011). By means of data collections, business schools may recognize their strengths and weaknesses and find out where further optimization is needed. Moreover, they can set specific incentives to promote performance and avoid underperformance. Taylor (2006), who analyzed research management in six leading research universities, states that all institutions in his study collect and use performance indicators.

4. Faculty quality: Both AACSB and EQUIS set high standards concerning the qualification of faculty in teaching and research. As a result, business schools applying for accreditation may recruit high-profile academics, paying them accordingly. Hedrick et al. (2010) found that in faculties with AACSB accredited programs, researchers were paid more and performed better than in those without accreditation. AACSB also requires "well-documented and communicated processes in place to manage and support faculty members over the progression of their careers consistent with the school's mission" (AACSB 2012, p. 53). Such formal mechanisms represent a further incentive for a scholar to join a business school and may foster research productivity. Faculty recruitment is a form of input control, which, again, is important when task programmability is low (Johnson 2011). According to Liefner (2003), the quality of the academic staff is the most important factor for the long-term success of a higher education institution.

5. Openness: EQUIS and AACSB expect that business schools foster connections with other higher education institutions and the corporate world. External cooperation may initiate learning processes and serve as a source of new ideas both in teaching and research, contributing to faculty development and productive research (Lejeune and Vas 2009).

Moreover, EQUIS in particular emphasizes internationalization of student body and faculty (Proitz et al. 2004). While international students and scholars may enrich the academic environment, a business school also needs to adapt to international standards in teaching and research if it wants to compete at the international level successfully. In doing so, it may need to further improve the quality of its services and its productivity.

6. Reputation: Finally, international accreditations may also foster research performance through their direct effect on reputation. As postulated by signaling theory (see for example Connelly et al. 2011), the main function of AACSB and EQUIS accreditations is to inform a business school's customers and partners about the quality of its services. For example, part-time working students and international students in particular use international accreditations as a quality differentiator (Zammuto 2008). Once accreditation has been achieved, the label's prestige and branding effects can make a business school more attractive to leading scholars and help to find appropriate partners (Temponi 2005). In doing so, accreditations reinforce the effects previously described, further increasing a business school's research performance.

We need to bear in mind that research is to some extent a prerequisite for international accreditation. Business schools that already have a high research performance may thus be more likely to apply for and achieve accreditation. However, AACSB adopted mission-oriented standards in 1991, making it possible for smaller institutions with less focus on research to be accredited (Heriot et al. 2009). Moreover, in recent surveys, business school deans and directors stressed that accreditations increase scholarly activity and organizational effectiveness (Roller et al. 2003, Lejeune and Vas 2009). Accreditation standards may thus indeed serve as incentives for improving an institution's performance. Given that both the process of seeking accreditation and the reputation effect after obtaining it may lead to a higher research performance, we state our main hypothesis as follows:

Hypothesis 1: Business schools that have achieved one or more international accreditations exhibit higher research performance.

Outside the context of accreditations, the implementation of a quality management system may contribute to higher research performance. In most cases, these systems imply the creation of a separate entity within the business school charged with coordinating various quality management activities. Drawing on the principal-agent theory of Jensen and Meckling (1976), we expect such an entity to make sure that academic and administrative staff fulfil their tasks according to the management's expectations. One of the main approaches to assure compliance is output control by means of performance indicators. As in the case of accreditations, systematic data collection may help the business school's managers to identify potential areas for further improvement.

Although quality management systems often involve a high degree of bureaucratization (Kogan et al. 2000), they are reported to improve the efficiency of administrative processes (Brookes and Becket 2007). Again, we observe a similar effect as in the case of accreditations: increased administrative efficiency may enable academic personnel to devote more time to research, in turn contributing to higher research performance. As accreditations and quality management require systematic data collection and improve organizational processes, we also expect the two approaches to be positively correlated with each other. However, a clear cause-effect relationship is difficult to assess. For example, a functioning quality management system could ease the accreditation process. At the same time, achieving accreditation may serve as an incentive for a business school to introduce a quality management system.

To ensure that quality management processes are not limited to teaching and learning evaluations, we consider only quality management systems that explicitly include research activities and administrative processes.

Hypothesis 2a: *Business schools that have implemented a quality management system covering research activities exhibit higher research performance.*

Hypothesis 2b: *Business schools that have implemented a quality management system are more likely to have achieved international accreditation.*

Finally, evaluating and discussing research projects within a business school's faculty is another important form of quality management. According to Kaufmann (2009), regular meetings or mentoring as well as informal and spontaneous feedback contribute to quality assurance and quality development in higher education. Owen-Smith (2001), who analyzed such interactions in a multidisciplinary neuroscience laboratory, concludes that, besides its evaluative function, “scientific skepticism” also serves as a control and coordination mechanism.

We call this form of quality management “feedback loops” and expect it to improve a business school’s research performance. In the higher education literature, the concept of feedback loops generally refers to the opinion of external stakeholders and course evaluations by students (Venkatraman 2007, Becket and Brookes 2006). However, in the present study we consider only faculty-internal feedback loops for research projects. Since engaging in an accreditation process may foster communication and cooperation within a business school (Lejeune and Vas 2009), we also expect such feedback loops to positively correlate with the achievement of an AACSB or EQUIS accreditation.

Hypothesis 3a: Business schools with internal feedback loops for research projects exhibit higher research performance.

Hypothesis 3b: Business schools with internal feedback loops for research projects are more likely to have achieved international accreditation.

4. Methods

For our statistical population, we used the higher education institutions registered in the *Top 1000 Business School Ranking* of the *Social Science Research Network* (SSRN) in June 2010. On the SSRN website, researchers from all over the world can publish their research results at an early stage as working papers. Since 2005, the SSRN has analyzed these publications in order to measure and compare the performance of higher education institutions. SSRN rankings are based on the number of papers posted by a higher education institution in the SSRN eLibrary and the frequency with which these papers are downloaded. The rankings are updated monthly and freely accessible.

By the end of 2010, we had contacted more than 1'250 school directors via e-mail and invited them to participate in an online survey. Of these, 99 responded in the first round. In a second round in spring 2011, we contacted 75 school directors from the top 250 business schools by telephone and obtained 18 additional feedbacks. The total of 117 responses corresponds to a feedback rate of nearly 10 per cent, which is rather low for online questionnaires in organizational research (Baruch and Holtom 2008).

Of the 117 institutions in the final sample, 41 were actually economic departments of universities registered as business schools on the SSRN website. The majority of the business schools (79 per cent) were public institutions. Their size ranged from a few dozen students to more than 14'000 and their budgets accordingly from 80'000 to over 300 million USD. On average, the business schools had around 2'100 full time students and a budget of 26.8 million USD. 42 per cent of the institutions were located in Europe, 37 per cent in the USA, 12 per cent in Asia and 9 per cent in other regions (Latin America, Africa and Oceania). Half of the business schools (59 to be exact) were accredited either by AACSB or EQUIS, or had achieved both international accreditations. Among the participating institutions, 46 had implemented quality management systems covering research activities, including administrative processes and chair planning. In order to measure feedback loops for research projects, we asked if research contributions by faculty members were regularly evaluated and results discussed within the faculty. 88 business schools said they had this type of feedback loops.

Using a similar approach to Aghion et al. (2010), we compared the research performance of business schools with their position in the *SSRN Top 1000 Business School Ranking*. Black and Caron (2006) analyzed the SSRN ranking of law schools as a measure of research performance. They concluded that SSRN rankings represent a valid and transparent instrument for measuring one important form of research output. By focusing on working papers, these rankings offer real time data and favor younger scholars and emerging schools. The SSRN rankings can therefore be seen as “leading” indicators of a faculty’s influence, while traditional indicators such as reputation surveys and citation counts have a more “lagging” character (Black and Caron 2006, p. 112).

A problem that persists with the SSRN rankings is their high volatility in the lower positions. Just a few downloads of a working paper can cause an upward shift of 75 positions. For this reason, we randomly chose three monthly rankings between May 2010 and April 2011 to calculate an average ranking. Additionally, to test our model we needed only to consider the business schools that participated in the survey. Following Currie and Pandher

(2011), who analyzed rankings of finance journals, we created four categories and classified the higher education institutions in our sample according to their absolute position in the entire ranking. Our four categories correspond to the classification used by the *Academic Journal Quality Guide* (Harvey et al. 2010) and represent the best 10 per cent (world elite), the following 25 per cent (above average ranking), the middle 40 per cent (average ranking) and the last 25 per cent (rather low ranking).

In our analysis, we controlled for the size of the business schools – operationalized with the number of full-time students – and the operating budget per student. Moreover, as business schools with little focus on research may have few publications on SSRN despite being internationally accredited, we needed to control for the institution's research orientation. We expected business schools offering a PhD program to be more research-oriented. Finally, we included the offer of specific programs for managers and chief officers (Executive Education) in our analysis. Executive Education can allow for synergies between research and practice. New research insights may be presented in the courses and critically questioned by students who have sound experience outside academia. This feedback can help optimize teaching and contribute to further research (Tushman et al. 2007). Executive Education also enables business schools to widen their financial base and acquire more resources. Moreover, it may boost public awareness of the business school and contribute to its reputation.

5. Results

Since our dependent variable is ordinal, we used an ordered-logit regression to test our hypotheses (see for example Agresti 2010). The ordered-logit regression estimates the influence of independent factors on the probability of a business school being in a certain ranking category. For the results to be meaningful, independent factors should not exhibit strong multicollinearity and have the same coefficients across all ordinal categories of the dependent variable. Both conditions were met by our data. In order to better interpret the effects of our accreditation and quality management variables, we analyzed five models that differed in the number of independent factors included (see table 1).

Table 1: Results of the ordered-logit regression

Variables (measurement level)		Model 0	Model 1	Model 2	Model 3	Model 4
		β (SE)	β (SE)	β (SE)	β (SE)	β (SE)
X1	International accreditation (dummy)		1.811*** (0.468)	1.803*** (0.469)	1.632*** (0.479)	1.632*** (0.479)
X2	Quality management system (dummy)			0.118 (0.379)		-0.008 (0.386)
X3	Feedback loops (dummy)				1.275*** (0.474)	1.276*** (0.477)
C1	Number of students (in thousands, interval)	0.636*** (0.126)	0.562*** (0.129)	0.561*** (0.130)	0.552*** (0.130)	0.553*** (0.130)
C2	Budget-per-student (in U.S. Dollars, interval)	0.093*** (0.026)	0.064** (0.026)	0.064** (0.026)	0.068*** (0.025)	0.068*** (0.025)
C3	PhD (dummy)	0.254 (0.405)	1.299*** (0.490)	1.302*** (0.490)	1.378*** (0.502)	1.378*** (0.502)
C4	Executive Education (dummy)	0.968** (0.416)	0.904** (0.420)	0.894** (0.421)	0.881** (0.426)	0.881** (0.426)
Pseudo R^2 (Nagelkerke)		**0.475**	**0.552**	**0.552**	**0.584**	**0.584**

Dependent variable: 4 SSRN ranking categories.
Significance levels * < 0.1, ** < 0.05, *** < 0.01
Standard errors in brackets.

The factors for the acquisition of an international accreditation (X1) and the presence of internal feedback loops for research projects (X3) proved to be positively and significantly related to business schools' ranking positions. Similarly, all four control variables (C1 to C4) exhibited mostly significant coefficients that pointed in the expected direction. In contrast, the effect of having a quality management system implemented (X2) was close to zero and not significant in either model 2 and 4. With a pseudo R^2 value of 0.584 in model 3 and 4, we can conclude that international accreditations, feedback loops and control variables explain to a large extent variation in the dependent variable. The results of the likelihood-ratio test proved to be highly significant, implying that our independent variables significantly improve the model.

In order to test our hypotheses about the relationship between international accreditations and other forms of quality management (*hypotheses 2b* and *3b*), we needed to estimate the correlations among independent factors (see table 2). As expected, international accreditations proved to be strongly correlated with feedback processes. However, we did not find any correlation between international accreditations and the implementation of a quality management system.

Table 2: Correlation matrix

Variables		Rank	X1	X2	X3	C1	C2	C3
X1	Int. accred.	0.424***						
X2	QM system	0.137	0.133					
X3	Feedback loops	0.322***	0.302***	0.178*				
C1	Students	0.442***	0.182**	0.020	0.160*			
C2	Budget	0.436***	0.288***	0.163*	0.071	0.020		
C3	PhD	0.297***	-0.302***	-0.025	-0.070	0.236**	0.245***	
C4	Ex. Education	0.323***	0.112	0.119	0.045	-0.041	0.319***	0.237**

Significance levels: * < 0.1, ** < 0.05, *** < 0.01

6. Discussion

Our results indicate that business schools with one or two international accreditations outperform other institutions in terms of ranking positions. This result holds true even when controlling for a business school's size and operating budget. Empirical evidence thus supports our *first hypothesis*: business schools that have obtained an international accreditation exhibit a higher research performance. Although many business schools already performed well before engaging in the accreditation process, international accreditations can further improve research performance through their effect on strategic management, resource allocation, openness and reputation. Since research performance affects reputation and reputation further increases research performance by making a business school more attractive to leading scholars and potential partners (Temponi 2005), the two factors may mutually reinforce each other.

The analysis did not provide any empirical evidence for a correlation between quality management systems and a business schools' research performance, so *hypothesis 2a* could not be confirmed. Similarly, our data did not support *hypothesis 2b* regarding the correlation between quality management systems and international accreditations. These results reflect some of the critical literature on quality management (see for example Lomas 2004; Temple 2005). Positive effects of quality management systems, such as increased efficiency of organizational processes and higher transparency (Stensaker 2003) may be outweighed by expanded bureaucratization (Kogan et al. 2000). Moreover, unlike international accreditations, quality management systems do not necessarily contribute to strategy development nor improve a business school's attractiveness to renowned researchers and external partners.

Besides the effects of international accreditations, internal feedback loops for research projects are significantly related to a business school's ranking position. Our analysis supported *hypothesis 3a*, confirming the importance of faculty members evaluating one another's research projects as a form of quality management (Kaufmann 2009, Owen-Smith 2001). As predicted in *hypothesis 3b*, these feedback loops are also positively correlated to international accreditations. Empirical evidence thus endorses the assumption that international accreditations foster faculty integration and cooperation within business schools (Lejeune and Vas 2009). The inclusion of feedback loops in the ordered-logit regression slightly decreases the coefficient of the factor for international accreditations (see model 4), which suggests that feedback loops partly act as a mediating variable on the relationship between accreditation and research performance.

Among the control variables, all of our factors proved to be significantly related to research performance in the way we expected. A business school's size and relative access to resources positively affect its position in the SSRN ranking. Moreover, the number of students and the budget-per-student variables positively correlate with achievement of international accreditations. Bigger and richer business schools are thus more likely to be accredited by AACSB or EQUIS. Finally, the positive and significant coefficient for our Executive Education variable supports the assumption that Executive Education programs contribute to the research performance of business schools (Tushman et al. 2007). The positive correlation between Executive Education and budget per student reflects the assumption that Executive Education may influence research performance by providing additional financial resources.

According to Shah (1997), the impact of quality management on changes in higher education cannot be easily separated from the effect of other factors. In our analysis, we could not directly consider the knowledge and skills of the academic personnel, which is likely to have a relevant impact on research performance and accreditation (Liefner 2003). Another problem that has to be addressed is causality. Our ordered-logit model does not indicate if it is the supposedly independent variable that affects the dependent one or vice versa. As previously described, causality may be a problem especially in the case of international accreditations: since higher education institutions must meet specific standards of education and research in order to be accredited, research performance may influence the probability of achieving accreditation. In order to test whether accreditations truly foster research performance one would need to compare the research performance of a business school before it seeks international accreditation to its performance after it has obtained one. Unfortunately, with the data at hand we were not able to conduct such an analysis.

Finally, a major limitation of this study was the survey's relatively low response rate, which makes it difficult to generalize the results. As statistical information about the business schools registered on SSRN was unavailable, we could not exactly assess to what extent our sample matched the population. We only know that AACSB and EFMD have accredited together more than 700 business schools (AACSB 2013, EFMD 2013). Assuming that most of them are among the 1,250 institutions in the SSRN ranking, the 50 per cent share of accredited business schools in our sample may correspond quite well to their proportion in the population. Moreover, an overview of the SSRN ranking confirmed that, as suggested by our sample, most business schools were located in Europe and the USA.

7. Conclusions

In the context of increasing international competition (Marginson 2006, Teichler 2004), research performance has become a central factor influencing a higher education institution's reputation and its ability to recruit the best students and most outstanding faculty. This study used quantitative empirical data to analyze whether international accreditations and other forms of quality management contribute to a business school's research performance as measured by ranking position. While international accreditations proved to be positively and significantly related to research performance, we did not find any empirical evidence for a relationship between quality management systems and ranking positions. Although the survey's low response rate makes the findings difficult to generalize, our results suggest that international accreditations provide specific incentives that can help to improve a business school's research performance. Among the relevant factors, we may point out the high standards concerning a coherent strategy and the quality of faculty as well as the accreditations' branding effect (Romero 2008, Lejeune 2011). Unlike international accreditations, many quality management systems do not cover these areas and focus instead on data collection, organizational effectiveness and control.

In this study we focused on business schools and took a broad international perspective. Further contributions might investigate the impact of accreditations and quality management in other types of higher education institutions and in single countries or regions. It would also be interesting to look at single variables in more detail and analyze, for example, differences between AACSB and EQUIS accreditations. A further differentiation of quality management systems may also be relevant since such systems vary greatly among higher education institutions (Billing 2004, Houston 2008). A new survey would need to include specific definitions and explanations in order to better distinguish different approaches to quality management and account for the existing diversity.

Acknowledgements

We sincerely thank Loran Lampart, Nadine Broghammer and Maria Olivares, who collaborated on this research project. We also thank Professors Bill McKinley and Ruth Alas, the reviewers of the CLADEA Annual Assembly 2012 and the reviewers of the Journal of Higher Education Policy and Management for their helpful comments and suggestions on prior versions of this paper.

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A.2
Differentiation or convergence?
The allocation of external funds among German and Swiss universities and its consequences for scientific production*

Abstract

One of the goals of higher education and research policy in Europe is to increase university performance through market-like steering mechanisms and a stronger focus on competitive external funds. However, the effect of such policies on the structure of national research systems and scientific production are disputed in academia. This study first assesses how increasing competition has affected resource acquisition by universities in Germany and Switzerland, two countries with similar higher education systems but different policy approaches at the federal level. In a second step, it analyzes how the specialization on different types of external funding – namely research grants from national and international funding agencies, government and industry contracts, and contributions from foundations – is related to the scientific production and consequently the reputation of a university. Empirical evidence supports the hypothesis of convergence towards similar patterns of resource acquisition, rather than increasing differentiation. It also suggests that scientific production is strongly associated with specialization on single types of funding, and that these association patterns differ depending on the type of university. These results have important implications for both university managers and policy makers.

Keywords: university, external funding, Gini coefficient, Balassa index, fixed effects regression, instrumental variable, Germany, Switzerland

* This paper has been written together with Benedetto Lepori and Andrea Schenker-Wicki.

1. Introduction

Most universities in continental Europe are public and funded primarily by the state through direct core contributions. External funding, which is funding from private or public sources acquired autonomously by researchers in competition with others, has traditionally played a minor role (see e.g. Jongbloed & Vossensteyn 2001, Lepori et al. 2007a, Lepori 2011). In the last 20 years, however, resource scarcity due to the exceptional growth of universities in both student numbers and research expenditures, and underperformance in research as compared to leading US universities (Bonaccorsi 2007, Jacobs and van der Ploeg 2006) have called for a more effective allocation of public funds. To achieve this goal, many European governments have implemented reforms aimed at increasing university autonomy, improving accountability, and creating a market-like environment (see e.g. de Boer et al. 2002, Kogan et al. 2006, Paradeise et al. 2009). The belief that funds should be allocated more selectively has led to an increasing focus on external, competitive public funding, and a growing importance of private funding (Geuna & Muscio 2009, Perkmann et al. 2013).

The effects of these policy approaches are contested in academia (see e.g. Hicks 2012). While some scholars stress the importance of fostering competition in order to modernize the European higher education system (van der Ploeg and Veugelers 2008), others have criticized such reforms as compromising scientific progress in the long run (Geuna & Martin 2003, Hicks & Katz 2011). Besides the new institutional frameworks introduced, such as the growing need for accountability and the use of performance indicators, funding reforms, and specifically the growing reliance on competitive funding, may affect the future development of higher education and research in several ways.

On the one hand, competitive funding has an impact on the *allocation of resources* among universities and, consequently, on the structure of national university systems including their inherent dynamics and power relations. The rationale behind funding reforms is that competition would lead to higher selectivity and a concentration of resources in the best institutions, increasing inequality among universities and forcing them to specialize in specific domains (Abramo et al. 2012, Horta et al. 2008). At the same time, competition often spurs imitation and mutual learning, particularly if the same benchmarks are used to assess performance (see e.g. Jha & Lampel 2014, Marginson 2002). Universities may thus take similar strategies and obtain comparable results. So far, empirical evidence on the effects of competition on resource allocation has been inconclusive, with both increasing (Xie 2014) and decreasing inequality (Halffman and Leydesdorff 2010, Ville et al. 2006) being documented.

On the other hand, external funding may also affect the *scientific output* of universities, their productivity, efficiency, and effectivity. Advocates of market-like steering mechanisms stress that competition sets incentives for quality, selects the best works, and optimizes the performance at the system level (Herbst 2007, cited in Hicks 2012). Other scholars point to negative unintended consequences, stressing that a high dependency on external funds may lead to research that is less innovative, with a weaker long-term impact (Geuna 2001, Butler 2003). Overall, empirical evidence is ambiguous again. At the national level, Auranen and Nieminen (2010) found no convincing evidence that political reforms aimed at increasing competitiveness leads to higher research performance.

A possible reason for the lack of empirical evidence is that the impact of competitive funding on universities varies depending on the *type of funding*. A variety of forms of external funding exist, the most common being research grants from national and international funding agencies, research contracts with government and industry, and contributions from foundations. These types of funding differ considerably in their objectives and requirements to applicants, and set different incentives for researchers, possibly leading to varying research outcomes. So far, several studies have analyzed external funding either at the level of single funding instruments (see e.g. Benavente et al. 2012, Chudnovsky et al. 2008, Jacob & Lefgren 2011) or differentiating the broad categories of public grants and private contracts (Beaudry and Allaoui 2012, Cherchye and Vanden Abeele 2005, Bolli and Somogyi 2011). However, systematic analyses at university level that account for the varying importance of different types of external funding are missing.

In this study, we contribute to the debate by analyzing five categories of external funds in Germany and Switzerland, tracking their evolution and their association with scientific production. These two countries are excellent examples of higher education systems with a long tradition of basic state funding and an increasing share of external funds. They both enjoy a high international reputation with several universities ranked among the best in Europe (CWCU 2015, THE 2015). Germany is also the largest economy in Europe and ranks fourth worldwide in number of scientific publications and third in citations, after the U.S. and the U.K. (SCImago 2013). Switzerland is much smaller but has a high share of excellent universities and is considered one of the most innovative and competitive countries worldwide (Dutta et al. 2014, Schwab 2014).

Our first research question relates to the debate on funding allocation and can be stated as follows: *how did the distribution of external funds among universities in Germany and Switzerland evolve and are there any differences for single types of external funds?* Our second question concerns the relation between external funds and scientific production: *how are different types of external funding associated with scientific production and what consequences may a change in the composition of external funds have for universities?* So far, no studies have comparatively analyzed differences between the main categories of external funding with respect to their effects on resource allocation and their association with scientific production. Empirical evidence providing a differentiated insight into possible consequences of the growing competition for funding is highly relevant for policy-makers, who need to know whether reforms have led to the expected outcomes and which measures may be taken to obtain better results. Knowing which types of funding are associated with scientific production is also essential for university managers that aim at increasing the reputation of their institutions.

The remaining part of the paper is organized as follows: in the next section, we present our theoretical framework and review previous findings. In section three, we present the higher education and research systems of Germany and Switzerland and analyze their development in the last 15 years by means of descriptive statistics. In section four, we test whether concentration of external funding, and thus inequality among universities, has increased using Gini coefficients and Balassa's index of revealed comparative advantage. Section five presents the econometric analysis for identifying association patterns between university specialization on specific types of external funding and scientific production, as measured by number of publications per person. We discuss our findings in section six and conclude in section seven by hinting at some policy implications.

2. Theoretical background and literature review

The increasing importance of external funds in European higher education is tightly related to the introduction of reforms linked to the concept of New Public Management (NPM) (de Boer et al. 2007, Ferlie et al. 2009). NPM emphasizes the efficiency gains of public service delivery through privatization and quasi-market competition, and shifts the focus of government steering approaches from inputs to outputs by introducing performance indicators and evaluations (Hallfman and Leydesdorff 2010). In the academic sector, NPM approaches have led to three broad consequences in university management and governance. First, governments have granted universities more autonomy with respect to the use of core funds, their internal organization, recruitment procedures and the definition of study programs and research activities (Estermann and Nokkala 2009, Estermann et al. 2011). This increase in autonomy came along with the introduction of managerial approaches and the "professionalization" of administrative functions within universities (Blaschka et al. 2014). Second, NPM implies growing competition for students and funds, which is reflected – among other things – in the increasing share of external funding to the total university budget (Geuna 1999, Lepori et al. 2007a). Third, the emphasis on output steering has led to the introduction of a number of performance measures and assessments that are partly relevant for future funding (see e.g. Whitley and Glaeser 2007). This tendency is also reflected in the increasing wish of sponsors to define research topics in advance and spur research towards societal and economic needs (Lepori et al 2007a).

2. 1 Convergence and differentiation in resource allocation

The overall effect of these reforms on the structure of national higher education and research systems has been widely discussed in terms of institutional differentiation (see e.g. Huisman 1995). Differentiation is seen as the main solution for many challenges in higher education and research, such as growing student numbers, increasing diversity of the student population, the need to foster research performance, and to produce more socially relevant results (van Vught 2008, Rossi 2010).

Market-like steering mechanisms and competition are generally expected to foster differentiation, as resources are not distributed equally and the gap between successful and unsuccessful institutions widens. Autonomously acting universities will tighten their profiles, focus on their strengths, find market niches, and specialize (Fumasoli and Lepori 2011, Fumasoli and Huisman 2013). Consequently, competitive research funding is assumed to lead to a concentration of resources in few institutions that have the necessary size, organizational structure, incentive system, and research culture to attract such funds (Horta et al. 2008). In the end, these processes will facilitate the emergence of large research oriented universities competing at the global level for world-class status (Abramo et al. 2012, Teichler 2008).

However, the complex interactions between agents at different levels of the system, and the many dimensions involved make it difficult to achieve consensus on the causes and dynamics of organizational diversity in higher education (Rossi 2010). While Horta et al (2008) and Xie (2014) present evidence of resource concentration among U.S. and U.K. universities, Shibayama (2011) does not find any relevant changes in the case of the Japanese National Research Grant. Halffman and Leydesdorff (2010) observe a weak tendency towards less inequality among the top 500 universities ranked in the Shanghai ranking and cannot confirm the hypothesis of emerging elite universities. Similarly, Ville et al. (2006) point to a decreasing inequality among Australian universities in terms of research performance, and Wu (2015) shows that funding of the Chinese Science Foundation has been distributed more equally over the years.

Hence, competition may also lead to the convergence of strategies and funding patterns, rather than differentiation. From a management perspective, such processes can be illustrated by the concept of strategic simplicity or, more precisely, competitive repertoire simplicity (see Chen and Miller 2012). In competitive dynamics theory, competitive repertoires consist of all actions that an organization uses to attract, serve, and keep customers, i.e. concrete market decisions such as price changes, product line or service alteration, and changes in the scope of operations (Miller and Chen 1996).[1] As managers

[1] Competitive dynamics is a subfield of the strategic management literature that goes back to the seminal works of Baum and Korn (1996) and Smith et al. (1992). It studies rivalry between organizations by means of specific competitive actions and reactions, their strategic and organizational contexts, and their drivers and consequences (see Chen and Miller 2012 for an overview).

tend to focus on actions that have proved successful in the past, competition can lead to less diverse competitive repertoires and thus strategic simplicity (Jah and Lampel 2014). Such processes may be the result of narrowly focused collective "lens of experience" and skewed information and learning systems (Miller 1993 cited in Ferrier & Lyon 2004). Considering successful organizations as a benchmark for evaluating performance may lead to imitation and thus strategic simplicity among the less successful organizations (Fiegenbaum et al. 1996, Giachetti and Lampel 2010).

If we consider universities as autonomous organizations competing in an increasingly market-like environment (Whitley and Glaeser 2014), we can apply the concept of competitive repertoire simplicity to illustrate how competition may lead to convergence of resources acquisition rather than differentiation. Scientific reputation is mainly based on research performance (Horta 2009), which can be measured as the number of publications and, more specifically, their impact, i.e. the number of citations (Toutkoushian et al. 2011). In this context, universities striving for higher reputation may adopt the same models as successful universities, trying to acquire more external funds in order to foster their research performance. In other words, universities will adapt to the increasingly competitive environment by imitating the strategies of successful institutions and learning from best practices (van Vught 2008).

These processes are also captured by the concept of institutional isomorphism proposed by DiMaggio and Powell (1983). Besides *mimetic* isomorphism, which is based on imitation and deliberate adoption of successful models, the authors identify forms of *coercive* and *normative* isomorphism, which may also be relevant in the case of universities. Coercive isomorphism originates from formal and informal pressures exerted by external organizations or by cultural expectations in society. Public universities are often required by law to conduct research and governments may exert pressure by setting the rules for resource allocation and limit the level of core funding. In contrast, normative isomorphism results from the professionalization of a specific domain, i.e. the definition and diffusion of a shared cognitive base and common working conditions among its representatives. From this perspective one can argue that acquiring external funds and publishing novel research have become integral tasks for all scholars, independently of the institution they are working in.

2.2 External funding and scientific production

The relationship between external funding and scientific production is ambiguous and strongly depends on the *type* of funding under consideration and, more specifically, on two distinct sets of features: first, on the way the *selection process* is organized and the requirements applicants need to fulfil; and second, on the *organizational setting* of the research conducted, including the objectives of funding and the degree of autonomy granted to researchers.

The selection process serves to identify the right candidates for research funding in order to increase the success probability of the research project and to maximize the returns of the money invested. The main problem of the selection process is that the sponsor does not always have the knowledge needed to assess the quality of a research project and depends on the scientific community for choosing the right candidates (Braun 1993). Moreover, as the outcomes of a project cannot be assessed in advance, the evaluation of proposals is always coupled to uncertainty. In the absence of other reliable criteria, the reputation of candidates and their previous academic achievements often serve as indicators for the chances of a project and thus play an important role in funding decisions (Viner et al. 2004). Resource allocation based on previous performance will create incentives for applicants to achieve better results (Auranen and Nieminen 2010). Depending on how heavily previous reputation weighs in the selection process, external funding may be associated with varying degrees of scientific production.

Concerning the organizational setting of external funding we distinguish three broad objectives that allow for a categorization into academic, thematic and innovation oriented funding instruments (Lepori et al. 2007b). Academic funding emphasizes scientific excellence, grants the researchers a high degree of autonomy and expects them to share their results with the scientific community through publications or conference presentations. This is the traditional setting for academic research that drives reputation at individual and university level, as most performance assessments and university rankings are based on publications, citations, or prizes (Horta 2009). In contrast, thematic and innovation-oriented funding serve more policy-oriented issues and stress the applicability of research. They can be seen as a general category of user-oriented funding that is transferred to society or industry and has a lower academic impact in terms of academic publications.

Depending on the type of external funding, the selection process and the organizational settings vary significantly, influencing scientific output and reputation. First, traditional *academic grants* from national or international funding agencies are highly competitive, with selection almost exclusively based on peer reviews and the reputation of candidates often playing a crucial role. Although user-orientation has become increasingly important, the majority of such grants serve purely academic projects and the promotion of young talents.[2] Previous studies have found a positive, though not always strong impact of academic grants on scientific production at the individual level, for example in the U.S. (Jacob & Lefgren 2011, Arora and Gambardella 2005, Azoulay et al. 2011), Canada (Beaudry and Allaoui 2012), Italy (Arora et al. 1998), Argentina (Chudnovsky et al 2008) and Chile (Benavente et al. 2012). Empirical evidence also suggests that academic grants are associated with higher efficiency (Cherchye and Vanden Abeele 2005) and more cooperation among researchers (Ubfal and Maffioli 2011).

Second, public research funds directly allocated by the government through *state contracts* are less selective and less dependent on academic reputation (Grimpe 2012). They are mostly user-oriented and address social or economic challenges rather than purely academic research, leading to output with lower academic impact. In a study on government contracting in the aeronautic domain, Goldfarb (2008) found that researchers maintaining a relationship with the sponsor experienced a decrease in publications. Other studies concluded that, although funds directly distributed by the U.S. congress were positively associated with publications, no such relationship could be found for citations (Payne 2002, Payne & Siow 2003).

Third, *industry contracts* are also very user-oriented, but their degree of selectivity varies considerably. Connolly (1997) and Blume-Kohout et al. (2009) argue that industry allocates resources to the universities that do the highest quality research. While this is true

[2] International grants, more specifically research grants from the European Union, display a high share of user-oriented funding. For instance, out of the total budget of the Seventh Framework Program of the EU (ca. 50 billion Euros without Euratom), 24 percent (12 billion Euros) were spent on the two academic oriented programs, Ideas and People, which include the grants from the European Research Council and the Marie Curie fellowships (European Commission 2015). Nonetheless, EU framework programs have also been found to be positively associated with scientific production (Defazio et al. 2009).

for large multinational corporations (MNC), many small or medium size enterprises (SME) operating at regional level tend to work with less-known and more locally-oriented universities. The association of industry contracts and scientific production thus remains ambiguous. On the one hand, there seem to be complementarity effects between the acquisition of private funds from industry and other academic activities (see e.g. Connolly 1997, Muscio et al. 2013, Blume-Kohout et al. 2014). On the other hand, several studies did not find any positive effect of private funding on scientific production (Beaudry and Allaoui 2012, Cherchye and Vanden Abeele 2005), at least not when industry contracts make up an important share of research funding (Bonaccorsi et al. 2006).[3]

Finally, *donations* and private grants from *foundation*s are not necessarily granted on a highly selective basis and do not always depend on previous performance. At the same time, they are less user-oriented than state or industry contracts and may provide the researcher with a high degree of autonomy. For this reason, it is possible that such types of funding are associated with high scientific production.

Summing up, we expect that universities with a large amount of grants from national funding agencies will exhibit higher scientific production. Such association patterns are also likely to occur with international funds and grants from foundations. In contrast, we do not expect universities specialized in state contracts to be academically highly productive, while in the case of industry contracts the situation is probably ambiguous. Table 1 summarizes our assumptions. It lists the different categories of external funding and indicates the type of selection, the type of objectives, and the expected association with research performance. Needless to say, this rough classification only captures general trends and does not account for the many existing exceptions.

[3] Bolli and Somogyi (2011) conclude that public external funds positively affect research productivity, whereas private funds are positively related to patent applications.

Table 1: Types of external funding, their main sources, characteristics, and association with research performance

Type of external funding	**Main funding source**	**Characteristics**	**Consequences on output**
Academic grants	National & international agencies	*Selection:* high selection strongly based on previous reputation *Objectives:* academic	Associated with high research performance
User-oriented grants	National & international agencies	*Selection:* high selection partly based on previous reputation *Objectives:* user-oriented	Weakly associated with high research performance
State contracts	National and regional governments, public organizations	*Selection:* rather low selection, reputation not always playing a central role *Objectives:* user-oriented	Not associated with high research performance
Private contracts	Business (MNC and SME)	*Selection:* both high selection (for MNC) and low selection (for SME) possible *Objectives:* user-oriented	Only MNC funding associated with high research performance
Donations, grants from foundations	Individuals, foundations	*Selection:* both high and low selection possible *Objectives:* rather academic oriented	Associated with medium to high research performance

3. External funding in Germany and Switzerland

3.1 Funding responsibilities

In both Germany and Switzerland, educational responsibility is almost exclusively located at the level of the member states (the *Länder* in Germany and the *Cantons* in Switzerland), with universities receiving most of their basic funding from the local government.[4]

[4] Switzerland has also introduced a compensation system that grants universities additional funds from other cantons and from the federal state according to their number of students and – to a small degree – their research activities. Moreover, Switzerland has two federal institutes of technology that have the status of technical universities and are funded primarily by the central state.

As opposed to education, the promotion of research lies within the purview of both the central government and the member states, with most competitive funding mechanisms being located at the federal level. The German Research Foundation (*Deutsche Forschungsgemeinschaft*, DFG) and the Swiss National Science Foundation (SNSF) are the two main research funding agencies. The DFG is the largest funding agency of its type in Europe and the main source of public external funding in the German higher education sector (DFG 2013b). In 2012, it had a total budget of 2.52 billion Euros, two thirds of which were provided by the central government and one third by the member states (DFG 2013a). The SNSF plays a similar role for Swiss universities. In 2013, it had a budget of about 780 million Euros, which – as opposed to the DFG – were almost exclusively provided by the central government (96.6 per cent) (SNSF 2014).

Besides the two main funding agencies, universities in Germany and Switzerland acquire considerable research funding from other, more applied state agencies, from contracts with the governments at both national and regional level, from cooperation with industry, and from foundations. Moreover, with the creation of the European Research Area, a new supranational level of funding has been established in Europe. Within less than 30 years, the annual budget of the European framework programs for research and development has expanded from around 600 million Euros in 1984 to almost 10 billion Euros in 2013 (State Secretariat for Education, Research and Innovation 2013), making international funding an integral part of national research systems. Initially, European funding was conceived as a complement to national research funding with a focus on research projects that had a "European added value" (see e.g. Annerberg et al. 2010). In the last years, however, European funding has increasingly begun competing with national funding schemes.

While exhibiting several similarities, the German and Swiss research systems have also considerable differences. First, a large part of public research in Germany takes place in non-university research institutions, among which the Max-Planck-Society is by far the largest and the one that is best known internationally. In Switzerland, although a few public research institutes exist, most public research takes place in universities. The second main difference between the two countries is that the German central government, together with the *Länder*, has recently begun a large-scale program promoting cutting-edge research and making selected German universities internationally more competitive (Hartmann 2006). This so-called Excellence Initiative is highly competitive, with funds being allocated in collaboration with the DFG. Like similar programs in other countries, such as the project 985 in China (see Zhang et al. 2013), the initiative aims at concentrating a great amount of resources in a small number of excellent universities, increasing their reputation and visibility. For this reason, we expect a higher concentration of public competitive funds in Germany than in Switzerland.

3.2 Types of universities

Two main types of institutions characterize the higher education systems of Germany and Switzerland: universities and universities of applied sciences (*Fachhochschulen*). Universities offer broad education at the Bachelor and Master level and are usually research-oriented. Universities of applied sciences were initially conceived as focused on teaching and practice-oriented training. In the last 20 years, however, they have started conducting research and development, which are generally more applied than in universities. Universities of applied sciences do not award PhD degrees, though they have increasingly been involved in PhD programs with universities and have a growing number of PhDs among their staff and faculty. Other types of higher education institutions include – particularly in Germany – universities of education, colleges of art and music, and colleges of theology. Due to their specific tasks, the different kinds of universities and colleges are not easily comparable. Therefore, this study focuses on public universities and universities of applied sciences.

3.3 Descriptive statistics

For German universities, most of the data stems from different university reports and surveys conducted by the German federal office of statistics (Destatis). Destatis presents parts of these figures at an aggregate level in its regular reporting series (see for example Federal Statistical Office of Germany 2013). However, data at university level is not published and had to be requested separately at several divisions of the federal office. For Swiss universities, collection proved to be easier, as most figures at university level are available online on the website of the Federal Statistical Office. All figures were then adjusted and matched into a single dataset. To collect publication data, we used Elsevier's online bibliographic database, Scopus. With about 21,000 sources, of which 20,000 are peer-reviewed academic journals (Scopus 2013), Scopus covers about 20 percent more items than Thomson Reuter's Web of Science (Falagas et al. 2008). Moreover, Scopus is less focused on English-speaking journals and thus more suitable for an analysis of German and Swiss universities.[5]

Table 2 shows descriptive statistics of the variables used in the analysis for the years 2000 and 2012, separately for universities and universities of applied sciences in Germany.[6] As we see, there are both common trends and differences between the two types of institutions. Universities are on average much larger than universities of applied sciences, counting three times more students, a higher number of scientific staff, and a budget about six times larger than universities of applied sciences. Both universities and universities of applied sciences have considerably grown between 2000 and 2012, although the latter ones have been growing at a higher pace, catching up to some extent with universities.

With respect to funding, we see that external funds have grown at a higher pace than the overall budget of universities and their expenditures. The share of external funding to total expenditures has thus increased from 17 to 24 percent for universities and from 5 to 11 percent for universities of applied sciences. Figures 1 and 2 present the evolution of the five main types of external funding graphically. For universities, DFG grants represent the main source of external funding and have strongly increased after 2006, presumably as a consequence of the excellence initiative. In contrast, they are almost non-existent for universities of applied sciences. The relative importance and evolution of other types of funding is similar for both types of universities. We note that public funding from the federal government has increased more than the other types of funding, surpassing industry contracts as the main source of external funds apart the DFG.

[5] The Scopus database is available online by subscription at www.scopus.com. With the Affiliation search option, one can identify all publications from a specific university and further differentiate them by scientific field.

[6] The statistical analysis, figures and graphs in chapter 3 and 4 have been computed using the statistical software R (R Core Team 2014).

Table 2: Summary statistics for German universities

	2002		2012		Change of mean	N
	Mean	**SD**	**Mean**	**SD**		
Universities						
Students	17'533	12'732	19'551	12'773	**12%**	77
Scientific staff	2'225	1'524	2'932	2'074	**32%**	77
Publications	711	589	1'464	1'199	**106%**	77
Total expenditures	201'985	130'533	240'227	163'358	**19%**	77
Total external funds (EF)	37'005	31'603	61'353	53'892	**66%**	77
EF to total expenditures	17%	6	24%	8	**41%**	77
Universities of applied sciences						
Students	4'494	3'043	5'996	3'428	**33%**	93
Scientific staff	341	223	530	327	**55%**	93
Publications	5	8	25	34	**400%**	93
Total expenditures	32'725	19'296	41'771	23'867	**28%**	93
Total external funds (EF)	1'623	1'266	4'358	3'091	**169%**	93
EF to total expenditures	5%	3	11%	6	**120%**	93

Total expenditures and total external funds are measured in 1'000 Euro at constant prices (2012 prices).

Figure 1: Evolution of types of external funds 1998-2012: universities (in 1'000 Euro and 2012 prices)

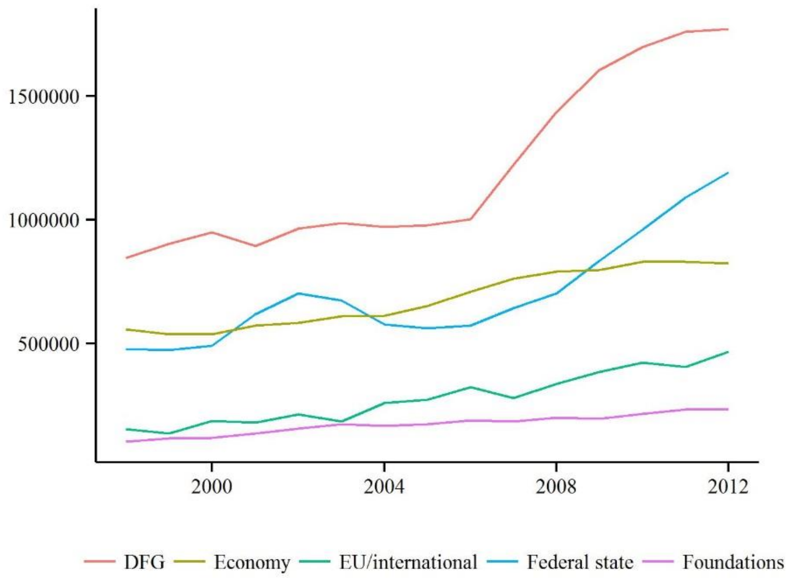
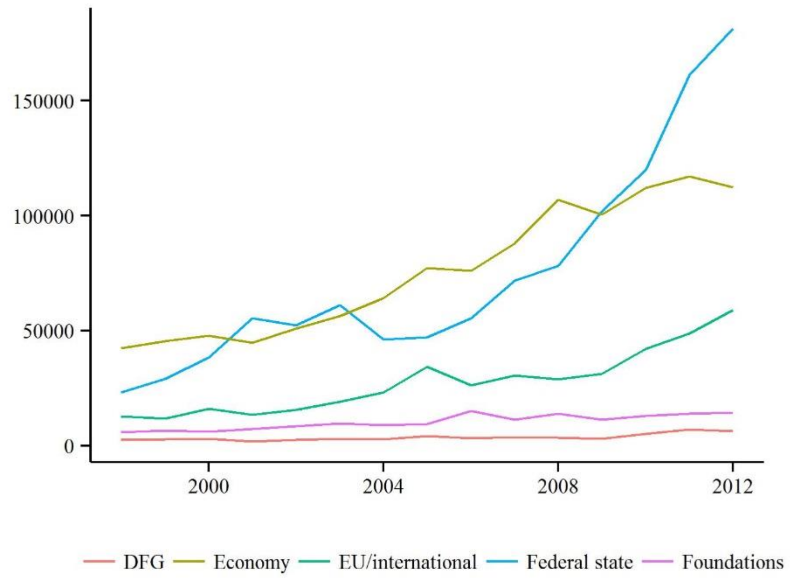


Figure 2: Evolution of types of external funds 1998-2012: universities of applied sciences (in 1'000 Euro and 2012 prices)



Traditional performance indicators of universities such as the number of publications and citations vary considerably depending on the scientific field under consideration (see e.g. Nederhof 2006). To illustrate these differences, table 3 reports descriptive statistics at the level of discipline groups for German universities. As expected, major differences exist. Whereas the number of students is larger in the social sciences and humanities, the operational expenses and external funds acquired are higher in the natural sciences and in engineering. Moreover, the natural sciences produce considerably more publications. These differences need to be taken into account when assessing the performance of whole universities.[7]

[7] Very similar patterns are found in Switzerland. Descriptive statistics for Swiss universities and universities of applied sciences are presented in appendix 1 and 2.

Table 3: Summary statistics for groups of disciplines in Germany

	Humanities		Social Sciences		Natural Sciences		Agric. & Forestry		Engineering	
	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012
Universities										
Students	6'010	6'146	4'941	4'948	3'886	4'507	907	1'219	3'061	4'471
Academic staff	440	582	239	344	584	777	166	194	537	648
Publications	23	68	24	99	430	844	81	161	70	187
Total expenditures	24'000	26'643	14'524	17'472	52'673	62'118	17'198	17'610	52'826	59'250
Total external funds (EF)	3'774	5'717	2'365	3'300	13'632	21'703	3'945	5'270	18'563	26'935
EF to total expenditures	14%	20%	19%	19%	23%	32%	20%	29%	31%	37%
Observations	*67*	*68*	*75*	*75*	*70*	*73*	*23*	*21*	*40*	*45*
Universities of applied sciences										
Students	574	428	1'834	2'229	747	890	719	826	1'860	2'702
Scientific staff	58	66	116	169	50	80	62	85	146	205
Publications	0	2	0	3	2	15	2	5	2	8
Total expenditures	1'910	1'997	4'653	6'544	3'193	3'725	3'565	4'698	10'872	12'684
Total external funds (EF)	61	96	246	601	189	484	359	668	708	1'705
EF to total expenditures	3%	3%	6%	9%	7%	12%	12%	13%	7%	14
Observations	*14*	*17*	*90*	*89*	*55*	*75*	*22*	*24*	*90*	*90*

Total expenditures and total external funds are measured in 1'000 Euro at constant prices (2012 prices).

4. External funding and diversity

We investigate possible consequences of increasing competition by analyzing the evolution of resource allocation both at the level of the higher education system and at the level of single universities. First, to test whether a concentration of external funding has taken place at the system level, we analyze the evolution of Gini coefficients over the years 2000 to 2012. In a second step, we turn to universities and investigate how their specialization on different types of external funding has changed by means of Balassa indexes.

4.1 Structural changes in external funding allocation

Gini coefficients are a measure of inequality proposed by Italian statistician and sociologist Corrado Gini and are often used to analyze income inequality among individuals or families within a country, or to compare countries in terms of wealth distribution (see for example Chin and Culotta 2014, Ravallion 2014). Gini coefficients take values between zero, in case every observed unit disposes of the same resources, and one, when only one unit has everything.[8] We follow Halffman and Leydesdorff (2010) and use a normalized Gini coefficient to allow for comparison of samples of different size. The formula can be stated as follows:

$$G_N = \frac{\sum_{i=1}^{n}(2i-n-1)x_i}{(n-1)\sum_{i=1}^{n} x_i} \tag{1}$$

where n is the number of observation units, in our case universities, and x_i is the amount of resources, for example external funds, of university i in the previously ordered sample. As an overall measure of inequality, the Gini coefficient does not say anything about the distribution of inequality within a sample. We therefore include Gini coefficients for the highest and the lowest quartiles in the analysis to assess whether concentration processes differ among the universities with more resources and those with less. Moreover, in order to examine the dynamics underlying concentration processes we report the share of the single quartiles to the total resources in the system at the beginning and at the end of the observed period (see Halffman and Leydesdorff 2010 for a similar approach).[9]

Figure 3 shows the evolution of Gini coefficients for total external funds, the number of publications, and the number of citations of traditional universities in Germany. Against the common expectation that higher competitiveness leads to a concentration of external funds, the distribution of resources has not become more unequal over the years. The overall Gini coefficients for external funds, publications, and citations have been rather constant at a level of about 0.5 over the years. However, we observe major differences between the highest and lowest quartiles. Among the best universities, inequality has kept constant or, as

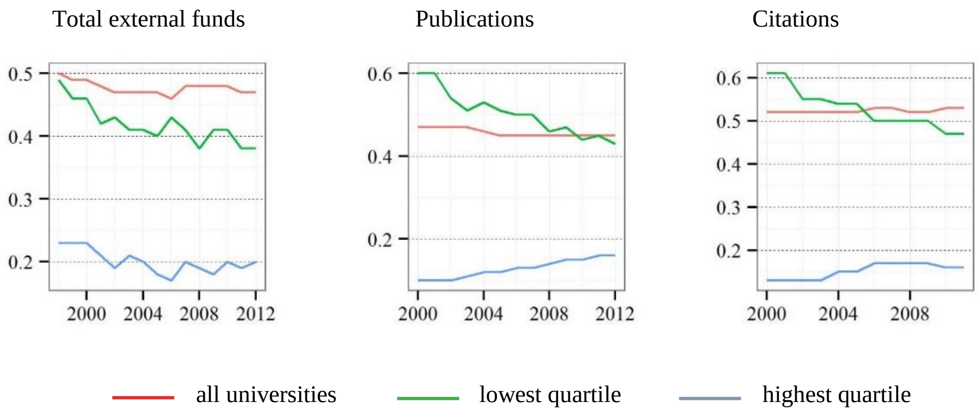
[8] Gini coefficients are based on the so-called Lorenz curve, which cumulatively plots the resources of all units, from the one with the least resources to the one with the most. In case all units disposed of the same resources, the Lorenz curve would be a straight line, and the Gini coefficient corresponds to the surface between this hypothetical line and the observed Lorenz curve (Halffman and Leydesdorff 2010).

[9] For example, if an increase in concentration within a quartile were due to the best universities improving their performance, the share of the corresponding quartile to total resources would increase. By contrast, if the increase in concentration were due to the worst performing universities becoming even weaker, the share of the quartile to total resources would decrease.

in the case of publications, has slightly increased over the years. In contrast, the lowest quartile displays a notable decrease in inequality.[10]

Figure 3: Distribution of external funds, publications and citations among German universities: Gini coefficients and share of single quartiles, 2000 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

	Total external funds			Publications			Citations		
	1998	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	3.20	3.95	0.75	2.33	3.83	1.50	1.55	2.13	0.58
Q2	13.44	14.58	1.14	13.36	13.93	0.57	11.21	11.02	-0.19
Q3	24.29	25.14	0.85	31.31	29.75	-1.56	28.69	27.14	-1.55
Q4	59.07	56.34	-2.73	53.00	52.49	-0.51	58.55	59.72	1.17

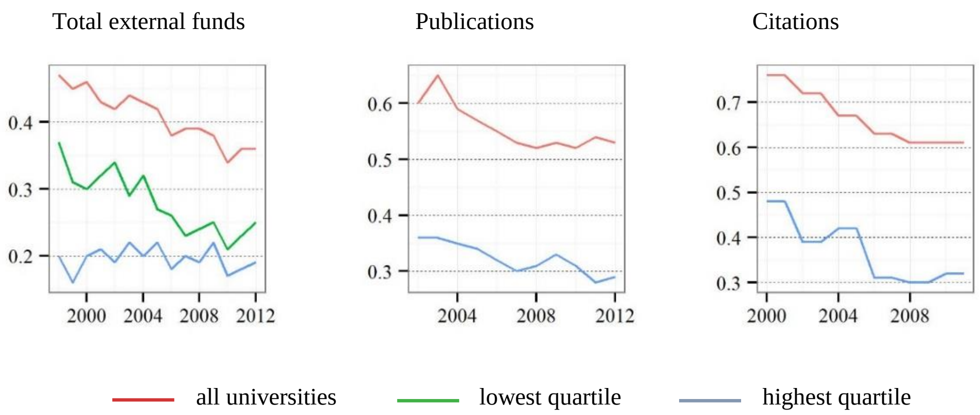
We also observe that the two upper quartiles account for more than 80 percent of total external funds and scientific output, indicating that the higher education system was already highly differentiated in 1998. While these differences have kept rather constant over time, there has been a slight tendency of the lower quartiles to increase their share of external funds and – to a less extent – publications at the expenses of the most successful universities.

[10] One needs to be careful when comparing Gini coefficients for the upper and lower quartiles, and the magnitude of their evolution, as they are based on figures of different size. In *absolute* terms, the same difference among units will have a larger effect in the lower quartiles, as it affects the *relative* distance between units more. For this reason, Gini coefficients for the lower quartiles are generally larger and their changes more pronounced.

These trends are more pronounced in the case of universities of applied sciences. As displayed in figure 4, the overall Gini coefficients for external funds, publications, and citations have declined among all universities of applied sciences. Notably, inequality of research output has also decreased among the best performing institutions.[11] The share of single quartiles to total funding confirm that these changes are due to the lower quartiles considerably increasing their shares at the expenses of the highest quartile.

Figure 4: Distribution of external funds, publications and citations among German universities of applied sciences: Gini coefficients and share of single quartiles, 2000 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

	Total external funds			Publications			Citations		
	1998	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	4.18	8.50	4.32	0	0	0	0	0	0
Q2	13.41	16.90	3.49	0	4.72	4.72	0	8.13	8.13
Q3	26.05	25.99	-0.06	6.24	17.51	11.27	13.43	21.76	8.33
Q4	56.37	48.61	-7.76	93.76	77.78	-15.98	83.67	68.63	-15.04

[11] We note that among universities of applied sciences, the relative distribution of publications and citations is particularly uneven, with many institutions not publishing at all. For this reason, figure 4 does not display the Gini coefficients for the lowest quartile of universities of applied sciences, as the results may be biased by the presence of many institutions without any publications or citations.

Appendix 3 and 4 report corresponding figures for the different types of external funding, and appendix 5 those of single discipline groups within universities. The overall trend of convergence rather than differentiation can be confirmed. Among the single types of external funding, a notable decrease of inequality in the case of EU-funding allocation stands out. Grants from the European Union are becoming an important funding source for a growing number of universities and are increasingly recognized as a central part of national funding systems.

Finally, these general trends also apply to Switzerland (see appendix 6 and 7).[12] A notable difference between German and Swiss universities concerns the distribution of federal funds and funds from the main national funding agency. While in Germany there has been a slight increase in concentration of these funds among the best performing universities after 2006, no such tendency is observable in Switzerland. This result may be directly related to the German Excellence initiative, i.e. the government's attempt to concentrate resources in few, internationally highly reputed institutions. Such explicit concentration attempts at the federal level do not exist in Switzerland.

Summing up, we note that overall external funds, the number of publications, and the number of citations have not been subject to notable concentration in the period 1998-2012. The higher education systems in Germany and Switzerland were already highly differentiated in the years 1998 and 2000 and the assumption that increasing competition for external funds and political discourse in favor of more focused funding leads to more inequality cannot be confirmed empirically. Especially among the least performing universities and the universities of applied sciences, inequality has clearly decreased: more institutions seem to have entered the competition for external funds and to have started publishing research results more actively. Accordingly, these preliminary findings at the system level rather support the hypothesis that competition has led to converging competitive strategies and institutional isomorphism.

[12] In the case of Switzerland, we only considered traditional universities, as data for universities of applied sciences was not available for the period before 2006. Moreover, since there are only 12 Swiss universities, we divided the institutions in a lower and an upper half instead of quartiles.

4.2 University specialization on external funding

To assess whether university strategies for resource acquisition have significantly converged, we compute Balassa indexes that measure the relative specialization of universities in acquiring different types of funding (Balassa 1965). For each university, the Balassa index measures the share of a specific type of external funds in relation to the share of the same type of funding in the whole population (for a similar approach, see Bonaccorsi et al. 2013). The index is computed as follows:

$$B_{i,j} = \frac{funding_{i,j}}{\sum_j funding_{i,j}} \left(\frac{\sum_i funding_{i,j}}{\sum_{i,j} funding_{i,j}} \right)^{-1} \quad (2)$$

Where $funding_{i,j}$ is the amount of type j of external funding acquired by university i. The Balassa index ranges between 0 and infinity. An index smaller than 1 indicates that a university is less specialized on a type of external funding than the average of all universities, while an index larger than one indicates an above-average specialization.

Table 4 presents averages of Balassa indexes for different quartiles of German universities in the years 2002 and 2012. The indexes are computed relatively to the whole population of traditional universities and universities of applied sciences. Moreover, the quartiles in 2012 are divided according to the values of 2002 in order to track the development of the same groups of universities. Again, we note a tendency towards convergence of acquisition patterns for different types of external funding. While universities with the lowest specialization reduced the gap to the national average, the Balassa indexes of those universities with the highest specialization decreased. Both the paired t-test and the Wilcoxon signed-rank test confirm that many changes, especially those among universities in the highest and lowest quartiles, are significant.[13] The only exception are grants from the DFG, for which acquisition patterns have not changed significantly.

[13] The Wilcoxon signed-rank test relaxes the t-test's normality assumption for distributions, which is not fulfilled for all types of external funding.

Table 4: Mean of Balassa indexes for different quartiles of German universities by type of external funding, 2002 (reference year for quartiles) and 2012

	Balassa index 2002		Balassa index 2012		Δ Mean	Significance tests	
	mean	sd	mean	sd		t	WSR
Total external funds							
Q1	0.582	(0.160)	0.673	(0.301)	0.091	1.294	64
Q2	0.901	(0.073)	0.994	(0.246)	0.094	1.762*	68
Q3	1.139	(0.087)	1.064	(0.284)	-0.074	-1.179	125*
Q4	1.511	(0.198)	1.345	(0.308)	-0.166	-2.637**	171**
Federal state							
Q1	0.477	(0.201)	0.753	(0.726)	0.276	1.794*	56*
Q2	0.918	(0.118)	0.824	(0.406)	-0.093	-1.089	135
Q3	1.186	(0.059)	0.892	(0.338)	-0.294	-3.893***	156***
Q4	1.731	(0.471)	1.534	(0.556)	-0.197	-1.339	142
DFG							
Q1	0.350	(0.216)	0.425	(0.314)	0.074	1.723	69
Q2	0.920	(0.116)	0.840	(0.400)	-0.080	-0.990	139
Q3	1.223	(0.067)	1.274	(0.452)	0.051	0.469	85
Q4	1.628	(0.253)	1.490	(0.487)	-0.139	-1.599	144
International/EU							
Q1	0.314	(0.150)	0.892	(0.856)	0.578	2.884*	24***
Q2	0.680	(0.100)	1.197	(1.150)	0.516	1.923*	40**
Q3	0.997	(0.116)	1.258	(1.173)	0.261	1.020	118
Q4	2.017	(0.774)	1.133	(0.496)	-0.884	-4.162***	201***
Business							
Q1	0.183	(0.142)	0.516	(0.306)	0.333	4.509***	14***
Q2	0.499	(0.092)	0.595	(0.268)	0.096	1.557	65
Q3	0.934	(0.175)	1.158	(0.549)	0.224	1.647	61
Q4	1.908	(0.573)	1.545	(0.826)	-0.363	-2.086*	158**
Foundations							
Q1	0.164	(0.190)	0.991	(0.673)	0.827	4.762***	8***
Q2	0.740	(0.120)	0.893	(0.729)	0.153	0.908	96
Q3	1.211	(0.253)	0.919	(0.520)	-0.292	-2.189**	157**
Q4	3.381	(2.224)	1.771	(1.142)	-1.610	-2.810**	178***

In both 2002 and 2012, universities are divided in quartiles according to Balassa indexes in 2002.

These results confirm that universities without any remarkable research activities have adopted similar strategies as more research-oriented universities and have started acquiring different types of external funding in order to foster their research performance. Again, these trends are even stronger among German universities of applied sciences (see appendix 8). Most universities of applied sciences were not specialized in the acquisition of external funds in 2002, as indicated by the low means of Balassa indexes for all quartiles. Consequently, in the case of total external funds, even institutions in the first quartile managed to increase their degree of specialization. Again, the only exception are funds from the DFG that keep playing a negligible role for universities of applied sciences.[14]

Similar conclusions can be drawn for Swiss universities (see appendix 9). However, as there are only 12 observations in Switzerland, the t-test and the Wilcoxon signed-rank test do not always provide significant results.

5. External funding and scientific production

Analyzing association patterns between types of external funding and scientific output at university level is challenging because cause-effect relationships cannot be observed directly and may be affected by multiple framework conditions. In order to enhance the explanatory power of our model, we therefore combine the panel structure of the data with an instrumental variable approach and apply a two-stage least square (2SLS) regression with fixed effects.[15]

5.1 Model specification

As a measure for scientific production, we use the *number of publications* (*publ*) from a university divided by the average number of academic staff employed at the same university one year earlier. This approach accounts for the time lag between the research process itself and the publication of its scientific findings that results from the writing of the article, the peer reviewing, and the revision process (see e.g. Cherchye and Vanden Abeele 2005). This time lag may vary depending on – among other factors – the scientific field of a publication and the journal type, and amounts from several months to a couple of years. At the aggregate

[14] In the case of foundations, the Balassa indexes vary considerably between 2002 and 2012, indicating a high dynamic in the distribution of this type of external funding among universities of applied sciences.

[15] The econometric models include both German and Swiss universities. For this reason, total expenditures and external funds of universities in Switzerland were converted to Euro and standardized according to the different price levels in the two countries.

level of a university, accounting for scientific output published one year after research funding has been spent seems a practicable approximation.[16]

As our main explanatory variable we use the average amount of *external funds acquired per academic staff* ($fund$). We examine different types of external funding separately in six different models, each taking into account total external funds, funds from the federal state, from the two national agencies (DFG and SNSF), from international organizations including the European Commission, from business, and from private foundations. The remaining part of the model is always kept constant. In doing so, we can assess how much the explanatory power of a model changes depending on the type of external funding included.[17]

The model also includes several control variables that are expected to influence the number of publications and citations per person. First, the size of a university, as measured by the *number of students* ($stud$), may affect scientific production through economies of scale (Dundar & Lewis 1995, 1998) or at least because in many scientific fields a critical mass is needed to conduct high quality research (von Tunzelmann et al 2003). Moreover, larger universities may profit from higher visibility and extensive internal resources, including the diversity of disciplines and potentials for interdisciplinary research. Second, the *expenditures per academic staff* (exp) is an indicator of the amount of available resources, the quality of the infrastructure, and the financial opportunities a university has, and should positively affect research performance (see e.g. Aghion et al 2008).[18] Third, the *number of students per academic staff* ($stud\_staff$) approximates the teaching load of scholars and indicates how much teaching-oriented a university is. We thus expect the variable to correlate negatively with research production. Finally, as shown in table 3, natural

[16] Counting the number of publications is a recognized measure for scientific output (Toutkoushian et al 2003). Similar to other bibliometric indicators, such as the number of citations, it has, however, several well-known limitations that we cannot discuss in detail in this study (see e.g. Haustein & Larivière for an overview). A potential problem of our measure for scientific output is that it does not allow for a differentiation of the overall number of authors and their relative contribution to a publication – or in other words – their order of appearance in the authors list. In bibliometric studies, such a differentiation is often used to measure research performance at the level of individual scholars (Abramo et al 2013). However, at the aggregate level of a university it is less crucial, as cross-institutional publications largely outweigh each other.

[17] Most variables measuring the amount of different types of external funding per academic staff were normally distributed, with the only exceptions being the share of external funds from business and from private foundations. These two indicators were thus recoded into intervals of equal size that can be assumed to be approximately metric.

[18] To avoid double counts we subtracted the amount of external funds included in the model from total expenditures when computing the measure for expenditures per academic staff.

and life sciences are more oriented towards publication of scientific results in international journals.[19] We control for the disciplinary profile of a university by including the *share of expenditures in the social sciences, humanities, and arts* (*soc_hum*) to the total expenditures.[20]

A common problem in empirical social research is endogeneity, which arises when the explanatory variable is correlated with the error term (see e.g. Wooldridge 2013). Endogeneity may be due to unobserved heterogeneity and omitted variables, simultaneity and measurement errors. In our model, unobserved heterogeneity and simultaneity are particularly relevant. On the one hand, both the number of publications per person as dependent variable and the share of external funds as independent variable may be correlated to unobserved variables such as the skills and the reputation of academic staff, or the internationality of the university. Though we partly account for the quality of staff by including expenditures per personnel, we cannot exclude that unobserved variables affect the correlation coefficients. For this reason, we use a fixed effects panel regression that eliminates the effect of constant unobserved variables.[21]

The other possible cause of endogeneity, simultaneity, occurs when both the dependent and the independent variables affect each other. In our model, such a problem arises if scientific production in terms of publications and citations per person affects the ability to acquire external funding. This may especially be the case for funding from the DFG, as such grants are given on the basis of, among other things, reputation and previous publication performance, which in turn depend on earlier funding (see e.g. Beaudry and Allaoui 2012). Such simultaneity issues can be addressed by using a two stage least squares regression model (2SLS), in which the endogenous variable, in our case external funding, is first predicted by a third variable, the instrument, and then replaced by its predicted values in the original regression model (see e.g. Bolli and Somogyi 2011 for a similar approach).

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[19] In the social sciences, the humanities, and the arts, academic contributions are less covered by databases such as Scopus or Web of Science, because of alternative publication types (i.e. books and edited volumes) or simply because they are published in German and thus less perceived at the international level.

[20] We do not include the share of natural and medical sciences because almost half of the universities do not have expenditures for these disciplines and the variables are far from being normally distributed. Moreover, to ensure that all variables in the models – including the controls – are normally distributed, we take their natural logarithm. This requires a minimal recoding of the variables in very small intervals to account for the few observations taking values of zero.

[21] The fixed effects model does not account for those unobserved variables that change over time. However, significant changes at the level of whole universities, such as the establishment of a high international reputation, only occur in the long-run (Salmi 2011) and we assume that unobserved variables do not change significantly over the considered period.

Instrumental variables should be good predictors of the endogenous variable, in our case external funding, without directly affecting the dependent variable. Following Aghion et al (2010), we use variables that reflect specific policy changes, namely the shifts in funding allocations over the years. To measure them we take the *share of different types of funding at the national level* ($fund\_nat$) to the overall expenses for research and development. These variables have a direct effect on the availability of different types of external funds and consequently on the ability of universities to acquire them. At the same time, they are not a direct predictor of the research performance of single institutions. The data mostly stems from the Eurostat database. Funding from the two national agencies was measured by collecting financial figures from their annual reports.

Summing up, our first stage model is defined as follows:

$$fund_{it} = \theta_0 + \theta_1 fund\_nat_{it} + \theta_2 stud_{it} + \theta_3 exp_{it} + \theta_4 stud\_staff_{it} + \theta_5 soc\_hum_{it} + \mu_i + v_{it} \tag{3}$$

where $fund_{it}$ represents the endogenous variables, which are the different types of external funding acquired by university i in the time-period t. The constant is given by θ_0, while $fund\_nat_{it}$ is the instrumental variable, μ_i is the time-invariant part of the error term, and v_{it} is the time-variant part of the error term. Accordingly, the second stage model can be formulated as:

$$publ_{it+1} = \beta_0 + \beta_1 \widehat{fund}_{it} + \beta_2 stud_{it} + \beta_3 exp_{it} + \beta_4 stud\_staff_{it} + \beta_5 soc\_hum_{it} + \alpha_i + \epsilon_{it} \tag{4}$$

with $publ_{it+1}$ indicating the dependent variable, i.e. scientific production as measured by number of publications per academic staff, and $\widehat{fund}_{it}$ being the predicted values for the different types of external funding from the first stage equation. The time-invariant error term is α_i and its time-variant part ϵ_{it}. As different association patterns of external funding and scientific production are possible for different types of universities, we apply the estimation model to both universities and universities of applied sciences separately.

5.2 Results

Tables 5 and 6 present correlation coefficients of the variables included in the model for the year 2011.[22] Most types of external funding are positively associated with publications per person for both universities and universities of applied sciences. Among universities, funds from the national agencies display by far the strongest correlation to research production (see table 5). Since this type of external funds is almost inexistent in universities of applied sciences, the corresponding coefficient is small and non-significant for these institutions (see table 6). In contrast, the coefficient for international funds is positive and significant for universities of applied sciences, but not significant in the case of traditional universities.

As for the control variables, all bivariate correlations could be confirmed in the expected direction for universities.[23] The number of students and the expenditure per staff proved to be positively related to research production, while a high teaching load and a stronger focus on the social sciences and the humanities are negatively associated with the number of publications per person. It is important to note, however, that many control variables are correlated among each other and/or with the variables for external funding. For example, in the social sciences and humanities the student to teacher ratio is rather high, while research expenditures and the amount of external funding are low due to the absence of expensive lab equipment. These multiple correlations need to be taken into account when analyzing the multivariate regression models.

Tables 7 and 8 present the results of the simple fixed effects regression and the second stage of the 2SLS regression for the six different models.[24] Among traditional universities, the positive association of total external funds and funds from the national agencies with scientific production stands out (see model 1 and model 3 in table 7). As shown by the adjusted R^2 values of 0.355 and 0.277, the two fixed effects models have the highest explanatory power, and none of the coefficients changes significantly when applying the instrumental variable approach. In contrast, the coefficient for funding from the state

[22] We restrict the correlation matrix to one year in order to account for cross-sectional variation only and exclude correlations across time. The same correlation matrices were computed for other years, yielding very similar results.

[23] In the case of universities of applied science, these associations are not so evident and not significant, which may point to the different context in which research takes place in these institutions.

[24] All models have been estimated using the statistical software Stata (StataCorp. 2011). The first stage results of the 2SLS regression are presented in Appendix 10 and 11.

changes from positive to negative in the 2SLS model, remaining highly significant and pointing to a negative association of external funding from the central state with publications per person. As for the other types of external funding, we observe a positive and significant association with scientific production in the 2SLS models. However, this result comes with a loss of significance of several other coefficients, pointing to possible shortcomings of the instrumental variable and reducing the reliability of the models.[25]

Apart from these few cases, the coefficients of the control variables keep constant across the different models and largely correspond to the expectations. The only exception is the share of social sciences and humanities, which displays very small and mostly non-significant coefficients. The reason for this may be that the overall disciplinary profile of the universities is widely accounted for by the fixed effects, and changes towards more or less social sciences and humanities are very small in the period under consideration.[26]

In the case of universities of applied sciences, the explanatory power of the fixed effects models strongly diminishes, with adjusted R^2 values raging between 0.117 and 0.166. Again, total external funds prove to be positively related to scientific production in both the fixed effects and the 2SLS models. In contrast to traditional universities, external funds from the federal state are positively related to the number of publications in universities of applied sciences, with all coefficients keeping roughly constant across both regressions (see Model 2 in table 8).

As for the other types of external funds, those from international funding agencies and from business display a significant coefficient that points to a positive association with publications per person. The positive coefficient of international grants confirms that the European Framework Programs have become an important source of research funding for universities of applied sciences. In the case of industry contracts, the evidence is less clear, as the result comes along with a loss of significance of other coefficients in the 2SLS model, pointing to possible shortcomings of the instrumental variable.

[25] For instance, such problems may occur if the instrument is highly correlated with the control variables and only weakly correlated to the endogenous variable, i.e. the different types of external funding. In the case of funding from industry, the low value of the F-test of excluded instruments points to the weakness of the instrument variable.

[26] Another possible reason may be the relatively high correlation among control variables observed in the correlation matrices.

Table 5: Correlation table for universities

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Publications per pers.	1.000										
2	Ext. funding total	0.487***	1.000									
3	Ext. funding state	0.229**	0.759***	1.000								
4	Ext. fund. nat. agencies	0.627***	0.674***	0.303***	1.000							
5	Ext. fund. int. agencies	0.067	0.515***	0.318***	0.020	1.000						
6	Ext. fund. business	0.268**	0.643***	0.416***	0.256**	0.176	1.000					
7	Ext. fund. foundations	0.116	0.202*	0.074	0.233**	0.163	-0.209*	1.000				
8	Students	0.334***	0.027	-0.019	0.308***	-0.179*	-0.111	-0.031	1.000			
9	Expenditures per pers.	0.545***	0.453***	0.423***	0.435***	0.127	0.474***	0.137	-0.016	1.000		
10	Students per pers.	-0.270**	-0.137	0.043	-0.159	-0.144	-0.200*	0.214**	-0.119	0.137	1.000	
11	Share of soc. & hum.	-0.642***	-0.592***	-0.515***	-0.390***	-0.198*	-0.493***	-0.101	-0.152	-0.604***	0.186*	1.000

Table 6: Correlation table for universities of applied sciences

Variables		1	2	3	4	5	6	7	8	9	10	11
1	Publications per pers.	1.000										
2	Ext. funding total	0.286***	1.000									
3	Ext. funding state	0.287***	0.710***	1.000								
4	Ext. fund. nat. agencies	0.070	0.384 ***	0.362***	1.000							
5	Ext. fund. int. agencies	0.214**	0.654***	0.411***	0.408***	1.000						
6	Ext. fund. business	0.171*	0.502***	-0.033	-0.116	0.091	1.000					
7	Ext. fund. foundations	-0.138	0.229**	0.053	-0.034	0.088	0.126	1.000				
8	Students	-0.023	-0.198**	-0.121	-0.128	-0.202**	-0.044	-0.250**	1.000			
9	Expenditures per pers.	0.090	0.339***	0.356***	0.171*	0.345***	0.022	0.151	-0.079	1.000		
10	Students per pers.	0.078	0.372***	0.319***	0.079	0.290***	0.006	0.266***	-0.043	0.798***	1.000	
11	Share of soc. & hum.	-0.184	-0.148	-0.384***	-0.052	-0.072	0.022	0.006	0.149	-0.341***	-0.264***	1.000

Table 7: External funds and publication performance among universities

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS
Constant	-13.840***	-13.930***	-15.960***	-16.930***	-14.670***	-12.580***	-15.190***	-2.529	-15.790***	-9.230***	-15.780***	-13.130***
	(0.687)	(0.696)	(0.748)	(0.88)	(0.759)	(0.970)	(0.758)	(3.827)	(0.748)	(3.308)	(0.738)	(1.595)
log(*fund_tot*)	0.573***	0.511***										
	(0.038)	(0.084)										
log(*fund_state*)			0.046***	-0.220***								
			(0.017)	(0.070)								
log(*fund_nat_ag*)					0.157***	0.408***						
					(0.022)	(0.068)						
log(*fund_int_ag*)							0.054***	0.832***				
							(0.010)	(0.198)				
log(*fund_busin*)									0.036*	1.454**		
									(0.020)	(0.588)		
log(*fund_found*)											0.063***	1.050***
											(0.018)	(0.201)
log(*stud*)	1.193***	1.210***	1.372***	1.460***	1.296***	1.156***	1.305***	0.191	1.359***	0.791***	1.367***	1.422***
	(0.066)	(0.070)	(0.070)	(0.082)	(0.070)	(0.083)	(0.071)	(0.343)	(0.071)	(0.295)	(0.070)	(0.142)
log(*exp*)	0.213***	0.245***	0.745***	0.897***	0.572***	0.301***	0.694***	-0.260	0.734***	-0.143	0.728***	0.152
	(0.069)	(0.079)	(0.075)	(0.093)	(0.077)	(0.108)	(0.075)	(0.319)	(0.075)	(0.410)	(0.075)	(0.191)
log(*stud_staff*)	-0.447***	-0.469***	-0.701***	-0.722***	-0.658***	-0.581***	-0.626***	0.505	-0.683***	-0.171	-0.690***	-0.792***
	(0.070)	(0.075)	(0.072)	(0.080)	(0.071)	(0.079)	(0.073)	(0.350)	(0.072)	(0.279)	(0.071)	(0.145)
log(*soc_hum*)	-0.013	-0.012	0.008	-0.079**	-0.016	-0.057**	-0.005	-0.059	0.000	0.170**	-0.003	-0.020
	(0.018)	(0.018)	(0.020)	(0.031)	(0.019)	(0.023)	(0.019)	(0.054)	(0.019)	(0.085)	(0.019)	(0.039)
N	1036	1036	1036	1036	1036	1036	1036	1036	1036	1036	1036	1036
adjusted R-sq.	0.355		0.251		0.277		0.265		0.246		0.255	
Instrument coeff.		345.50***		77.30***		55.33***		114.20***		3.51***		179.60***
F-test of excl. instr.		243.33		75.73		125.03		18.04		6.93		32.89

The FE models present the results of the fixed effects panel regression and the 2SLS models the second stage results of the instrumental variable approach (equation 4). In the latter case, the *fund*-variables correspond to predicted values of the explanatory variables. The dependent variable is log(*publ*) in all models. The instrumental coefficient and the F-test of excluded instrument refer to the first stage of the 2SLS regression (equation 3, presented in Appendix 10 and 11). Standard errors are given in parentheses and significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: External funds and publication performance among universities of applied sciences

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS	FE	2SLS
Constant	-17.390***	-13.660***	-20.89***	-20.44***	-22.170***	-13.950	-21.700***	-14.950***	-21.120***	-9.797***	-22.150***	-41.900***
	(1.308)	(2.545)	(1.230)	(1.43)	(1.219)	(9.310)	(1.244)	(3.378)	(1.238)	(3.215)	(1.253)	(15.05)
log(*fund_tot*)	0.442***	0.828***										
	(0.053)	(0.230)										
log(*fund_state*)			0.108***	0.152**								
			(0.022)	(0.073)								
log(*fund_nat_ag*)					-0.014	6.393						
					(0.065)	(6.598)						
log(*fund_int_ag*)							0.061*	0.998**				
							(0.035)	(0.414)				
log(*fund_busin*)									0.068***	1.022***		
									(0.019)	(0.195)		
log(*fund_found*)											0.001	-0.879
											(0.013)	(0.659)
log(*stud*)	1.498***	1.044***	1.896***	1.848***	2.017***	0.823	1.970***	1.214***	1.924***	0.621*	2.015***	3.472***
	(0.140)	(0.300)	(0.128)	(0.151)	(0.128)	(1.295)	(0.130)	(0.372)	(0.130)	(0.354)	(0.129)	(1.130)
log(*exp*)	0.142	-0.002	0.336**	0.299**	0.477***	-0.382	0.478***	0.691***	0.390***	0.284	0.476***	1.201*
	(0.125)	(0.153)	(0.131)	(0.144)	(0.131)	(0.978)	(0.130)	(0.193)	(0.128)	(0.236)	(0.131)	(0.621)
log(*stud_staff*)	-0.226	-0.188	-0.225	-0.176	-0.367**	0.761	-0.375**	-0.611***	-0.317**	-0.286	-0.365**	0.270
	(0.159)	(0.164)	(0.164)	(0.181)	(0.162)	(1.271)	(0.162)	(0.235)	(0.161)	(0.296)	(0.162)	(0.604)
log(*soc_hum*)	0.072**	0.068*	0.076**	0.074**	0.078**	0.196	0.078**	0.071	0.072*	0.002	0.079**	0.125
	(0.036)	(0.037)	(0.037)	(0.037)	(0.037)	(0.170)	(0.037)	(0.049)	(0.037)	(0.070)	(0.037)	(0.093)
N	1159	1159	1159	1159	1159	1159	1159	1159	1159	1159	1159	1159
adjusted R-sq.	0.166		0.135		0.117		0.120		0.125		0.118	
Instrument coeff.		343.60***		158.90***		38.94		251.60***		367.50***		-282.1
F-test of excl. instr.		62.66		102.70		1.05		12.77		35.28		2.20

The FE models present the results of the fixed effects panel regression and the 2SLS models the second stage results of the instrumental variable approach (equation 4). In the latter case, the *fund*-variables correspond to predicted values of the explanatory variables. The dependent variable is log(*publ*) in all models. The instrumental coefficient and the F-test of excluded instrument refer to the first stage of the 2SLS regression (equation 3, presented in Appendix 10 and 11). Standard errors are given in parentheses and significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Discussion

The results from the regression models – especially those for traditional universities – are in line with the findings of previous studies at the individual level conducted in other countries. For instance, the positive association of academic grants from the National Science Foundation in the United States (Arora and Gambardella 2005) or the Fund for Scientific and Technological Research in Argentina (Chudnovsky et al. 2008) with the publication performance of single researchers could be confirmed at the aggregate level of whole universities in Germany and Switzerland. Similarly, academic grants from international organizations seem to be positively related to scientific output, matching for example the findings of Defazio et al. (2009).

At the same time, the analysis reveals important differences between universities and universities of applied science. While funds from the federal state are negatively related to the research output of universities, a positive association can be found for universities of applied sciences. The reason for this difference might be the small amount of core contributions that the latter receive for research (see e.g. Lepori 2008). Universities of applied sciences are thus more dependent on external funding than traditional universities for conducting research and publishing. Since they focus on applied and user-oriented projects (De Weert 2011, Lepori and Kyvik 2010), researchers in universities of applied sciences do not fully match the requirements for academic grants and tend to acquire more funds from the federal state.

A similar argument of a lack of core funding and limited alternative funding options may also apply to industry contracts. Although empirical evidence is less clear in this case, external funds from business seem to be positively related to the scientific production of universities of applied sciences, while no such relationship is found for universities. However, the lack of empirical evidence may also be caused by the non-linearity of association patterns between external funds from business and scientific output. As shown by Bonaccorsi et al. (2006), small shares of industry contracts may positively affect the number of publications, while a large share of such contracts has a negative effect.

Summing up, the overall positive association of the total amount of external funding with publications per person observed for both universities and universities of applied sciences confirms the *productivity effect* that an increase in the share of external funds might have. At the same time, these association patterns vary considerably across different types of external funding and different types of universities. Policy-makers should be aware of these differences when considering on which funding sources to focus in order to foster the research performance of universities.

Moreover, the *distributional effects* of an increase in competition also need to be considered. As shown in the first part of the empirical analysis, both external funds and scientific output have not been subject to notable concentration from 1998 or 2000 to 2012. The higher education systems in Germany and Switzerland were already highly differentiated at the beginning of the observation period (see also Huisman et al. 2007) and the increase in competition has rather led to the convergence of strategies than to additional differentiation. Universities with a lower level of research have started imitating the strategies of more successful institutions, securing contracts and grants more actively and increasing their relative share of external funds.

Policy reforms aimed at increasing competition may thus foster the scientific output of the research system through the overall productivity effect of external funds, but not through distributional effects leading to the concentration of resources in the best institutions. If policy makers aim at increasing the research performance and the number of publications of all universities in the system, increasing the share of competitive funding might be the right measure. If, however, the aim is to diversify the higher education system further and concentrate most resources in a small number of worldwide leading universities, a different approach is probably needed. Rather than increasing overall competition, a feasible option would be to select a small number of universities in a structured process and then grant them special, long term funding.

Moreover, while the overall increase in publications may be an argument in favor of more external funds, policy makers should pay particular attention to the interplay between the productivity and distributional effects of different types of funding. For instance, grants from the DFG have been found to be positively associated with scientific production, but the corresponding Balassa indexes did not change significantly over time. Competition for funds from the DFG has thus not considerably widened, probably because of the demanding selection criteria and the central role of reputation and previous performance for funding allocation. In contrast, an increasing number of universities has started acquiring funds from the federal state, although this type of external funding is not always related to higher research production. Policy makers need to be aware of these differences and make sure that the types of external funding being expanded are related to the desired outcomes.

7. Conclusion

The goal of this study was to analyze two possible consequences of policy reforms aimed at more competition for research funding: the effect on the distribution of external funds among universities and the association of these funds with scientific production. The analysis differentiated between five types of external funding and two types of universities.

In opposition to the general assumption that more competitive funding leads to a concentration of resources in the best institutions, no empirical evidence for increasing differentiation could be found. The only exception was a slight concentration of public external funds among the upper quartile of universities in Germany, probably related to the implementation of the Excellence initiative. Most of the findings rather pointed to a decreasing inequality among institutions and to a convergence of acquisition patterns, confirming the assumptions of strategic repertoire simplicity and institutional isomorphism. Universities without any remarkable research activities have adopted similar strategies as more research-oriented institutions, increasing their relative share of external funding. These developments are particularly pronounced among universities of applied sciences, which hints at their growing role as research institutions.

As for the association of external funding and scientific production, the findings confirmed the positive effect of academic grants from national funding agencies among traditional universities, and of grants from international agencies among universities of applied sciences. Interestingly, external funding from the federal state proved to be positively related to the number of publications per person in universities of applied sciences, while a negative association was found in traditional universities. Positive association patterns were also found for industry contracts, although the observed relationship may be biased by endogeneity problems.

Policy makers need to be aware of both distributional and productivity effects when designing reforms. For instance, if their goal is to concentrate resources in few universities, simply increasing competition for external funds may not be the best option. Moreover, if they demand that universities acquire more external funds, they should be aware of the different effects that single types of funding may have for universities and universities of applied sciences. If reforms aim at increasing performance, a more nuanced approach that accounts for these differences may be useful.

Among the main limitations of the study was the inability to observe association patterns of external funding and scientific production directly in such complex organizations as universities. Endogeneity remains a problem that cannot always be fully addressed, especially in cases where good instrument variables are missing. Nonetheless, the study demonstrated that in-depth analyses are possible at the aggregate level of universities and similar comparative studies could be repeated in other contexts at national and especially international level. To this end, however, comparable panel data over an adequate period of time needs to be collected. Such studies are often hindered by the lack of reliable databases at national level or substantial differences across countries in the way data is collected. For this reason, ongoing projects aimed at creating common international databases, such as the European Tertiary Education Register (ETER) are of particular importance.

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Appendix

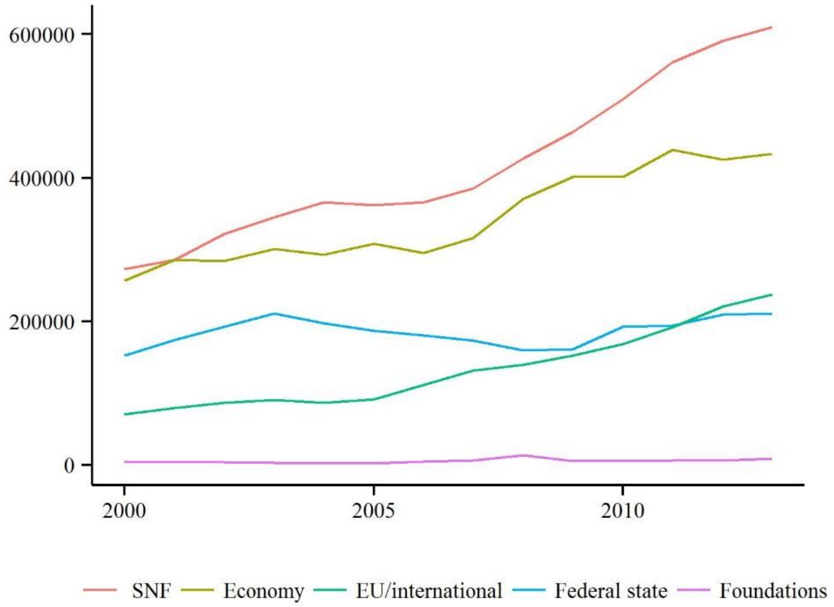
Appendix 1

Descriptive statistics for universities and universities of applied sciences in Switzerland (incl. graphs indicating the evolution of different types of third party funds)

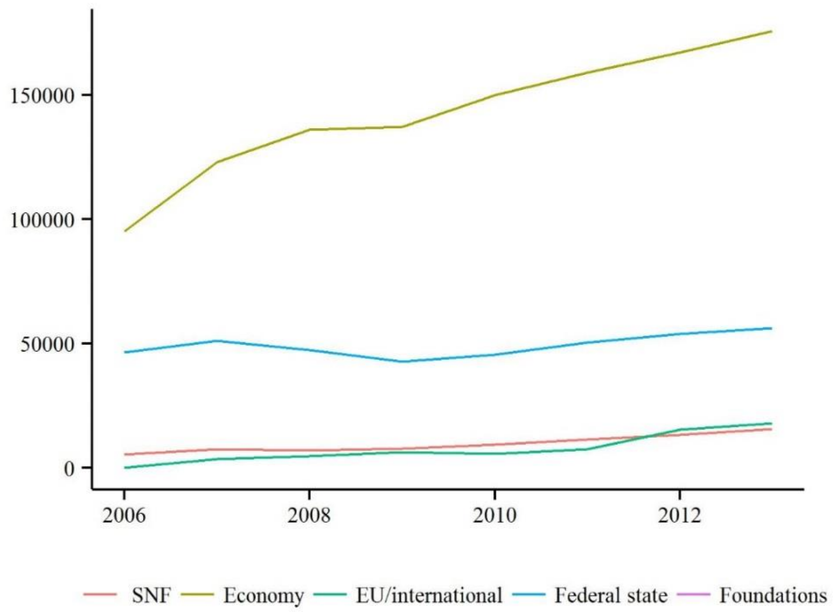
Universities						
	2000		**2012**		**Change of mean**	**N**
	Mean	**SD**	**Mean**	**SD**		
Students	8'032	5'666	11'476	6'830	**43%**	12
Scientific staff	2'278	1'929	3'515	2'561	**54%**	12
Publications	681	708	1'980	1'873	**191%**	12
Total expenditures	371'259	299'710	607'406	479'961	**64%**	12
Total external funds (EF)	71'620	51'185	133'187	102'351	**86%**	12
EF to total expenditures	19%	11	22%	4	**16%**	12
Universities of applied sciences						
	2006		**2012**		**Change of mean**	**N**
	Mean	**SD**	**Mean**	**SD**		
Students	6'197	3'500	9'266	5'547	**50%**	7
Scientific staff	2'810	1'912	4'919	3'392	**75%**	7
Publications	16	11	74	47	**363%**	7
Total expenditures	195'959	114'834	332'552	197'857	**70%**	7
Total external funds (EF)	30'398	12'323	50'306	18'935	**65%**	7
EF to total expenditures	17%	6	17%	5	**0%**	7

Total expenditures and total external funds are measured in 1'000 Swiss Francs at constant prices (2012 prices).

Evolution of types of external funds 2000-2013: Swiss universities
(in 1'000 Swiss Francs and 2012 prices)



Evolution of types of external funds 2000-2013: Swiss universities
of applied sciences (in 1'000 Swiss Francs and 2012 prices)



Appendix 2

Descriptive statistics for universities and universities of applied sciences in Switzerland at the level of single discipline groups

Universities	**Humanities**		**Social Sciences**		**Natural Sciences**		**Medicine & Health**		**Engineering**	
	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012
Students	2'545	2'216	3'678	5'201	2'023	2'344	1'154	1'391	1'877	5'153
Academic staff	410	504	472	911	967	1'058	610	865	873	1'983
Total expenditures	42'149	46'193	47'480	83'755	134'418	163'334	130'619	171'558	107'037	227'844
Total external funds (EF)	5'239	8'337	9'821	24'595	34'906	54'774	36'479	52'295	25'855	72'518
EF to total expenditures	13%	19%	22%	29%	29%	34%	25%	29%	22%	24%
Observations	*8*	*10*	*12*	*11*	*9*	*11*	*7*	*8*	*5*	*3*

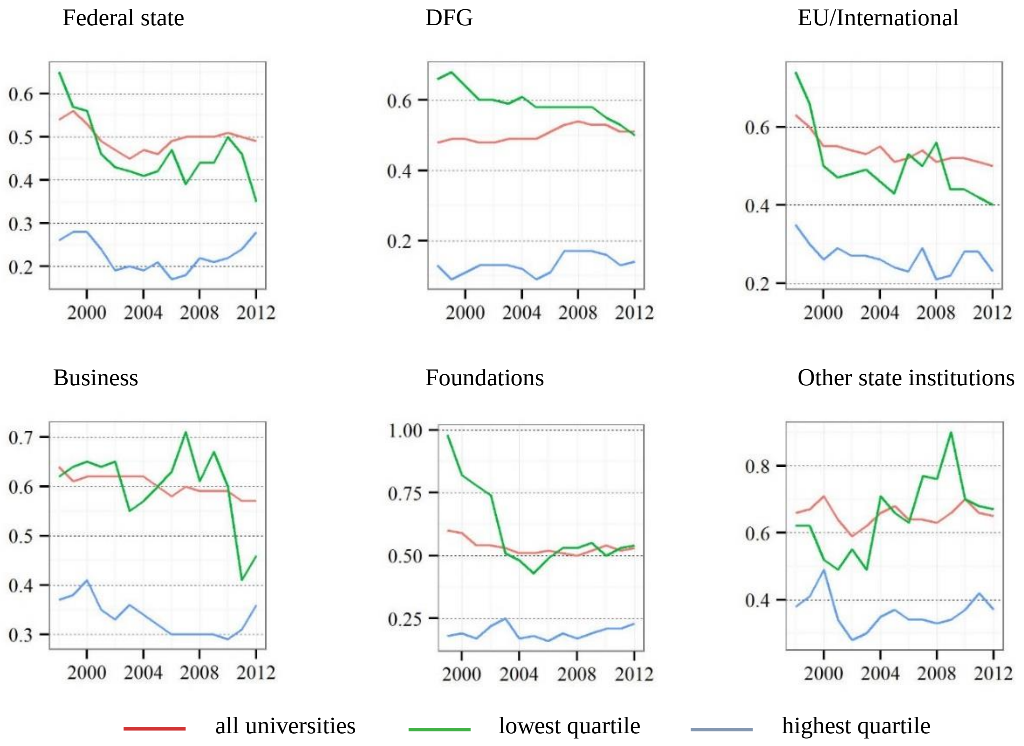
Universities of applied sciences	**Humanities**		**Social Sciences**		**Natural Sciences**		**Medicine & Health**		**Engineering**	
	2006	2012	2006	2012	2006	2012	2006	2012	2006	2012
Students	485	838	2'874	4'200	1'644	1'951	438	1'276	413	599
Scientific staff	226	346	1'060	1'469	527	941	444	785	190	349
Total expenditures	13'556	60'601	71'510	90'265	71'510	114'068	14'603	38'553	16'592	27'346
Total external funds (EF)	6'536	21'653	11'103	26'671	11'103	16'580	1'089	4'703	2'779	4'625
EF to total expenditures	35%	36%	37%	30%	17%	16%	6%	14%	18%	18%
Observations	*2*	*2*	*7*	*7*	*7*	*7*	*5*	*5*	*7*	*7*

Total expenditures and total external funds are measured in 1'000 Swiss Francs at constant prices (2012 prices).

Appendix 3

Distribution of single types of external funds among German universities: Gini coefficients and share of single quartiles, 1998 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

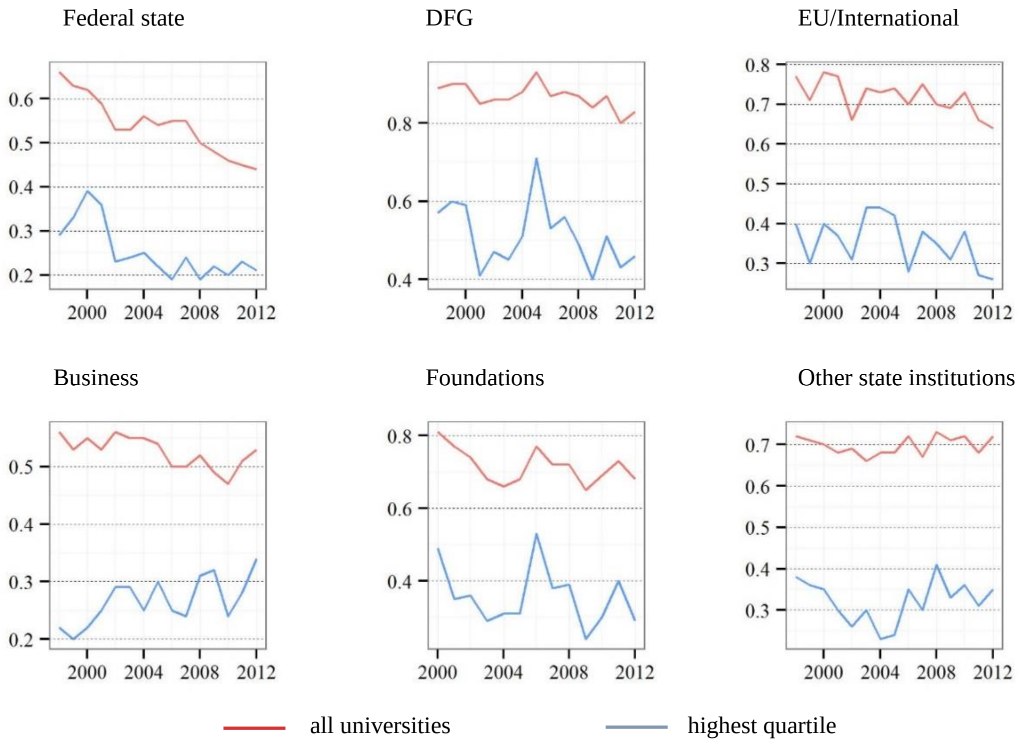
	Federal state			DFG			EU/International		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	1.56	3.04	1.48	1.82	2.02	0.20	0.82	3.41	2.59
Q2	12.25	14.5	2.25	14.27	11.34	-2.93	9.26	13.00	3.74
Q3	23.89	25.43	1.54	27.23	27.81	0.58	20.45	23.77	3.32
Q4	62.3	57.03	-5.27	56.69	58.83	2.14	69.47	59.82	-9.65

	Business			Foundations			Other state institutions		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	1.65	2.85	1.2	0	2.39	2.39	0.51	0.83	0.32
Q2	8.22	11.25	3.03	6.17	11.24	5.07	7.33	7.34	0.01
Q3	16.62	20.52	3.9	25.12	25.1	-0.02	19.69	18.86	-0.83
Q4	73.51	65.38	-8.13	68.71	61.27	-7.44	72.47	72.98	0.51

Appendix 4

Distribution of single types of external funds among German universities of applied sciences: Gini coefficients and share of single quartiles, 1998 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

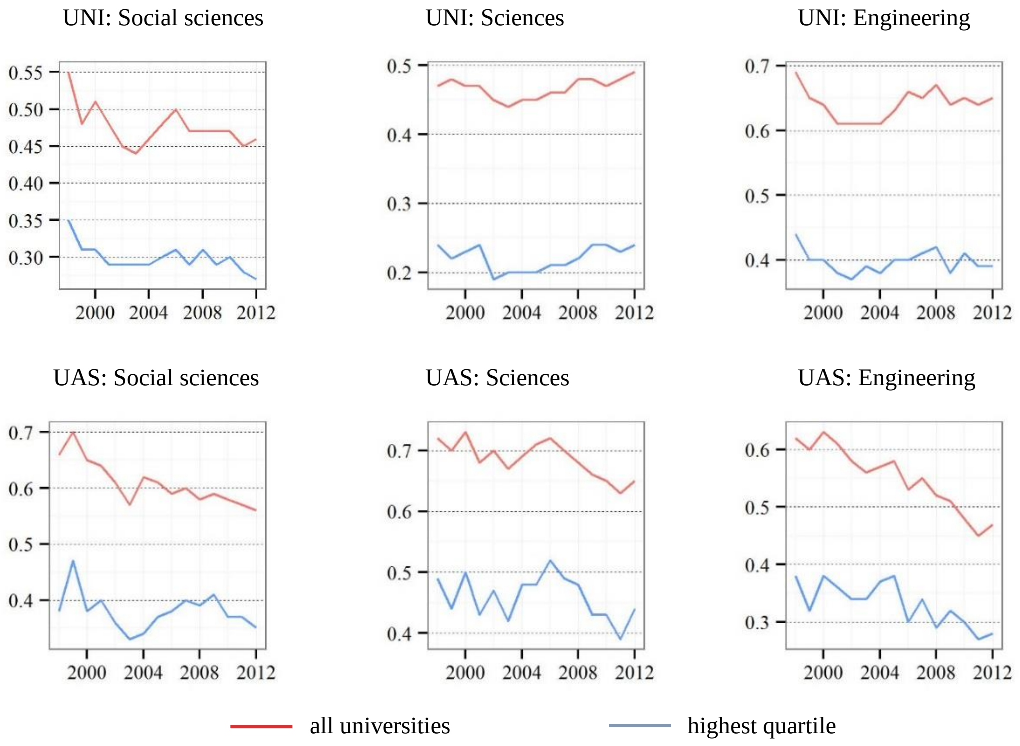
	Federal state			DFG			EU/International		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	0.07	5.11	5.04	0	0	0	0	0.18	0.18
Q2	6.68	14.67	7.99	0	0	0	1.17	6.82	5.65
Q3	18.75	25.26	6.51	0.03	7.58	7.55	13.4	21.64	8.24
Q4	74.50	54.96	-19.54	99.97	92.42	-7.55	85.43	71.36	-14.07

	Business			Foundations			Other state institutions		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	0.85	4.06	3.21	0	0	0	0	0	0
Q2	10.47	11.89	1.42	0	4.72	4.72	2.98	2.64	-0.34
Q3	25.24	20.77	-4.47	6.24	17.51	11.27	17.85	16.58	-1.27
Q4	63.44	63.29	-0.15	93.76	77.78	-15.98	79.18	80.78	1.60

Appendix 5

Distribution of total external funds among discipline groups of German universities (UNI) and universities of applied sciences (UAS): Gini coefficients and share of single quartiles, 1998 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

	UNI: Social sciences			UNI: Sciences			UNI: Engineering		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	2.97	5.57	2.60	2.44	2.94	0.50	0.07	0.25	0.18
Q2	10.57	13.47	2.90	14.98	13.01	-1.97	5.06	6.34	1.28
Q3	21.19	25.35	4.16	26.26	27.69	1.43	19.24	21.65	2.41
Q4	65.28	55.62	-9.66	56.32	56.35	0.03	75.63	71.77	-3.86

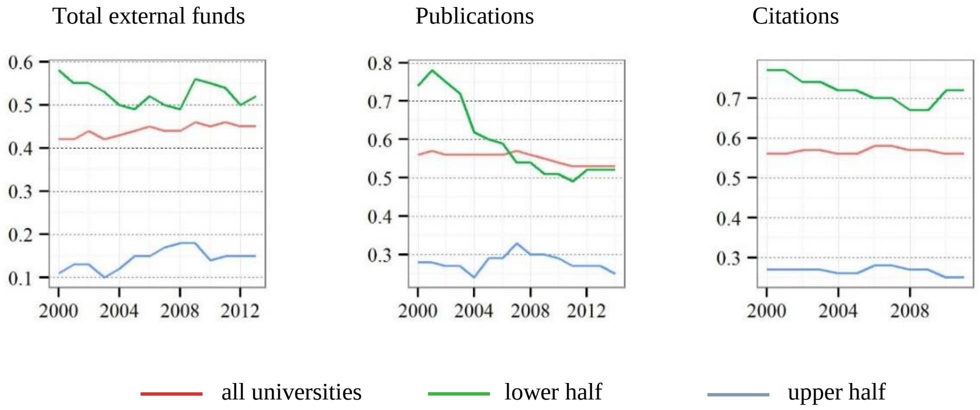
	UAS: Social sciences			UAS: Sciences			UAS: Engineering		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	0	2.03	2.03	0	0.88	0.88	0.25	4.74	4.49
Q2	3.48	10.13	6.65	2.72	6.25	3.53	7.35	14.01	6.66
Q3	23.97	24.06	0.09	17.47	19.77	2.30	22.28	25.15	2.87
Q4	72.55	63.78	-8.77	79.81	73.11	-6.70	70.11	56.1	-14.01

As several institutions only acquire small amounts of funding, the lowest quartile has not been displayed.

Appendix 6

Distribution of external funds among Swiss universities: Gini coefficients and share of single quartiles, 2000 to 2012

Evolution of Gini coefficients



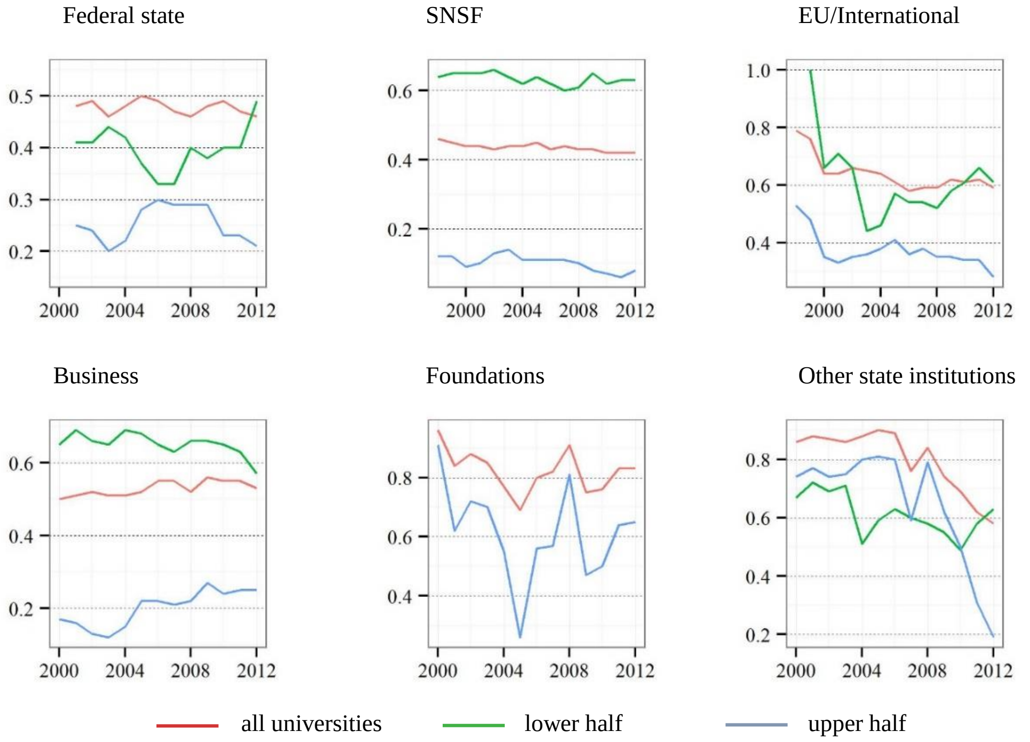
Share of single quartiles to total (in percent)

	Total external funds			Publications			Citations		
	1998	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	4.56	3.74	-0.82	0.77	2.93	2.16	0.45	1.10	0.65
Q2	16.74	14.02	-2.72	12.18	10.66	-1.52	12.39	10.44	-1.95
Q3	32.26	33.38	1.12	29.84	29.25	-0.59	30.57	30.36	-0.21
Q4	46.44	48.85	2.41	57.21	57.16	-0.05	56.59	58.10	1.51

Appendix 7

Distribution of different types of external funds among Swiss universities: Gini coefficients and share of single quartiles, 2000 to 2012

Evolution of Gini coefficients



Share of single quartiles to total (in percent)

	Federal state			SNSF			EU/International		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	0.91	3.29	2.38	0.67	2.56	1.89	0	1.31	1.31
Q2	12.58	14.99	2.41	17.05	16.89	-0.16	7.39	7.06	-0.33
Q3	26.78	31.67	4.89	37.11	36.37	-0.74	27.74	29.35	1.61
Q4	59.74	50.05	-9.69	45.18	44.18	-1.00	64.87	62.28	-2.59

	Business			Foundations			Other state institutions		
	2000	2012	Δ	2000	2012	Δ	2000	2012	Δ
Q1	2.85	3.05	0.20	0	0	0	0.28	1.35	1.07
Q2	16.26	13.95	-2.31	0	0.61	0.61	2.32	7.91	5.59
Q3	30.98	29.99	-0.99	1.85	9.49	7.64	10.73	35.98	25.25
Q4	49.91	53.01	3.10	98.15	89.9	-8.25	86.67	54.76	-31.91

Appendix 8

Mean of Balassa indexes for different quartiles of German universities of applied sciences by type of external funding, 2002 (reference year for quartiles) and 2012

	Balassa index 2002		Balassa index 2012		Δ Mean	Significance tests	
	mean	sd	mean	sd		t	WSR
Total external funds							
Q1	0.135	0.047	0.351	0.19	0.216	5.853***	5***
Q2	0.24	0.024	0.412	0.147	0.172	5.647***	13***
Q3	0.331	0.031	0.524	0.245	0.193	3.705***	29***
Q4	0.508	0.141	0.630	0.303	0.122	2.192**	91*
Federal state							
Q1	0.073	0.065	0.466	0.31	0.393	6.47***	5***
Q2	0.243	0.036	0.674	0.376	0.432	5.436***	8***
Q3	0.419	0.069	0.904	0.577	0.485	4.208***	38***
Q4	0.895	0.32	1.025	0.963	0.13	0.614	140
DFG							
Q1	0	0	0	0	0		
Q2	0	0	0.002	0.004	0.002	3.086***	0***
Q3	0.002	0.003	0.075	0.123	0.073	2.892***	5***
Q4	0.058	0.074	0.019	0.038	-0.038	-2.201**	249***
International/EU							
Q1	0.007	0.013	0.635	0.916	0.628	3.348***	4***
Q2	0.128	0.048	0.826	0.989	0.698	3.511***	36***
Q3	0.354	0.072	0.416	0.54	0.062	0.584	172
Q4	1.169	0.685	0.799	0.949	-0.37	-1.689	236**
Business							
Q1	0.075	0.067	0.549	0.698	0.474	3.242***	0***
Q2	0.271	0.054	0.686	0.588	0.416	3.591***	31***
Q3	0.446	0.057	0.516	0.388	0.07	0.904	136
Q4	1.069	0.274	1.012	0.98	-0.057	-0.272	181
Foundations							
Q1	0	0	0.043	0.059	0.043	3.571***	0***
Q2	0.021	0.038	0.901	1.135	0.88	3.78***	1***
Q3	0.274	0.081	0.352	0.489	0.078	0.762	168
Q4	1.065	0.869	0.326	0.424	-0.738	-3.307***	260***

In both 2002 and 2012, universities of applied sciences are divided in quartiles according to Balassa indexes in 2002.

Appendix 9

Mean of Balassa indexes for lower (M1) and upper (M2) half of Swiss universities by type of external funding, 2002 (reference year for lower and upper half) and 2012

	Balassa index 2002		Balassa index 2012		Δ Mean	Significance tests	
	mean	sd	mean	sd		t	WSR
Total external funds							
M1	0.699	0.198	0.995	0.119	0.296	2.389*	0**
M2	1.381	0.484	1.067	0.237	-0.314	-1.981	19*
Federal state							
M1	0.724	0.133	0.984	0.261	0.260	2.927**	1*
M2	1.387	0.344	1.001	0.473	-0.386	-2.269*	20*
DFG							
M1	0.529	0.317	1.027	0.454	0.498	3.86**	0**
M2	1.453	0.425	1.490	0.044	0.036	0.211	10
International/EU							
M1	0.24	0.238	0.701	0.694	0.462	1.665	3
M2	1.265	0.963	1.211	0.646	-0.054	-0.306	11
Business							
M1	0.57	0.360	0.749	0.226	0.179	1.159	6
M2	1.523	0.575	1.132	0.540	-0.391	-2.525*	18
Foundations							
M1	0	0	0.525	1.287	0.525	1	0
M2	23.466	54.982	9.660	17.452	-13.806	-0.576	12

In both 2002 and 2012, universities are divided into a lower and an upper half according to Balassa indexes in 2002.

Appendix 10

First stage regression results of the 2SLS approach: universities

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	FE	FE	FE	FE	FE	FE
fund_nat_tot	345.500*** (22.150)					
fund_nat_state		77.300*** (8.883)				
fund_nat_nat_ag			55.330*** (4.948)			
fund_nat_int_ag				114.200*** (26.890)		
fund_nat_busin					3.511*** (1.334)	
fund_nat_found						179.600*** (31.310)
log(*stud*)	-0.480*** (0.069)	-0.281* (0.147)	-0.343*** (0.126)	0.668** (0.291)	0.500*** (0.121)	-0.483*** (0.144)
log(*exp*)	0.128** (0.056)	0.103 (0.148)	0.474*** (0.117)	0.744*** (0.270)	0.696*** (0.125)	0.324*** (0.138)
log(*stud_staff*)	0.336*** (0.069)	0.615*** (0.154)	0.782*** (0.139)	-0.624** (0.305)	-0.433*** (0.120)	0.525*** (0.145)
log(*soc_hum*)	-0.008 (0.014)	-0.348*** (0.035)	0.130*** (0.027)	0.063 (0.062)	-0.111*** (0.031)	0.021 (0.033)
N	1036	1036	1036	1036	1036	1036
F-test of excl. instruments.	243.33	75.73	125.03	18.04	6.93	32.89

Models 1 to 6 present the first stage results of the 2SLS regression (equation 3), with the *fund_nat*-variables indicating the instruments. The dependent variables are the different types of external funding log(*fund*). Standard errors are given in parentheses and significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix 11

First stage regression results of the 2SLS approach: universities of applied sciences

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	FE	FE	FE	FE	FE	FE
fund_nat_tot	343.600*** (43.410)					
fund_nat_state		158.900*** (15.680)				
fund_nat_tot			38.940 (38.060)			
fund_nat_tot				251.600*** (70.390)		
fund_nat_busin					367.500*** (61.870)	
fund_nat_tot						-282.100 (190.20)
log(*stud*)	0.644*** (0.097)	-0.244 (0.216)	0.127 (0.083)	0.423*** (0.155)	0.103 (0.293)	2.085*** (0.417)
log(*exp*)	0.196*** (0.073)	0.352* (0.181)	0.111* (0.066)	-0.375*** (0.121)	-0.228 (0.211)	0.992*** (0.329)
log(*stud_staff*)	0.283*** (0.101)	-0.088 (0.240)	-0.132 (0.088)	0.538*** (0.163)	0.783*** (0.291)	0.399 (0.439)
log(*soc_hum*)	0.007 (0.020)	0.016 (0.050)	-0.019 (0.018)	0.004 (0.033)	0.069 (0.059)	0.057 (0.088)
N	1159	1159	1159	1159	1159	1159
F-test of excl. instruments.	62.66	102.70	1.05	12.77	35.28	2.20

Models 1 to 6 present the first stage results of the 2SLS regression (equation 3), with the *fund_nat*-variables indicating the instruments. The dependent variables are the different types of external funding log(*fund*). Because in the case of national agencies, international agencies, and foundations external funding only weakly correlated with the corresponding instrument variables we took *fund_nat_tot* as instrument. Standard errors are given in parentheses and significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A.3
Setting the stage for university research: Varying approaches and best practices among funding agencies in Europe

Abstract

In the wake of reforms aimed at increasing competition among universities, funding agencies have become central players of science policy in charge of allocating a considerable share of public research funds. These agencies differ considerably across countries in terms of their organization and their funding schemes, placing the search for best practices high on the political agenda. Although scholars have repeatedly discussed possible consequences of different funding approaches, empirical evidence based on cross-country analyses is largely missing. The present study first proposes a framework for categorizing agencies according to their funding profiles. In a second step, it applies fuzzy-set Qualitative Comparative Analysis (QCA) to investigate best practices for the promotion of university research in Western Europe. It identifies four causal combinations of agency characteristics and context factors associated with high scientific production and comprising a focus on investigator-driven project funding, on fellowships, or on large excellence programs. Moreover, the results stress the importance of a high funding level and point to caveats related to thematic funding. These findings are particularly relevant in the context of the creation of a common European Research Area and the rapid expansion of funding at supranational level.

Keywords: university research, funding agency, Europe, cluster analysis, fuzzy-set QCA

1. Introduction

In the last twenty to thirty years, most industrialized countries, as well as many developing ones, have implemented reforms to foster their higher education and research system, increasing not only its efficiency but also its responsiveness to external demands and expectations. Apart from granting universities more autonomy and introducing new accountability and performance measures (see e.g. Whitley and Glaeser 2007), governments have partially replaced traditional institutional funding by project funding in order to foster competition and allocate research funds more efficiently (Millar and Senker 2000, Lepori et al. 2007a). Moreover, an increasing focus on the returns of research spending has led governments to increase the share of research oriented towards societal, economic, and political needs at the expense of free academic research (see e.g. Braun 2003, Gulbrandsen 2005).

With the gradual shift from institutional university funding to project funding, the importance of funding agencies – i.e. the organizations in charge of allocating public funds for research and development (R&D) competitively – has considerably increased. Since the late eighties and nineties, many governments have created new funding agencies, reformed existing ones, expanded their budgets, and/or broadened the scope of their tasks and activities (OECD 2003, Lepori et al. 2007a). This expansion has often been accompanied by an increased tendency by authorities to earmark and specify the budget of funding agencies in greater detail (Skoie 1996, Lepori et al. 2007a), and to direct funding towards more applied research (Slipersaeter et al. 2007).

Despite these common international trends, however, funding agencies have remained deeply embedded in national policies and national research systems (Slipersaeter et al. 2007). As a result, they vary considerably in terms of their degree of autonomy from the state, their organization, their mission and the funding streams they manage (Reale et al. 2012). In the light of this great diversity, a highly relevant question is whether some models of funding agencies are better suited to foster research at universities, and whether best practices can be identified. To date several important conceptual and qualitative studies on funding agencies have been carried out (see e.g. Braun 1998, Benner and Sandström 2000).

However, there is a lack of systematic comparative studies at the international level based on quantitative data, focusing on different types of agencies, and identifying best practices.

Given these premises, the study has two aims. First, it develops a framework for categorizing funding agencies according to their tasks, missions and, consequently, their funding schemes. It applies this framework to funding agencies in Western Europe, a particularly interesting sample for several reasons. In Western Europe, almost every state has its own funding agencies, which are deeply rooted in national research policies and thus very diverse (Lepori et al. 2007a). At the same time, the context they face has become very similar over the last years. With the creation of the European Research Area, research policy has become an important topic at European level, and countries have begun coordinating their policies and elaborating common goals (see for example Barré et al. 2013, Luukkonen and Nedeva 2010). The first research question can thus be stated as follows: *how much do national funding agencies in Western Europe differ in terms of their funding schemes and can different types of agencies be determined?*

The second aim is to identify best practices. To do this, the study applies Qualitative Comparative Analysis (QCA) to the sample of states included in the analysis. QCA is a rather recent method developed by Raging (1987, 2000) and increasingly applied in many academic disciplines, including political science, sociology, economics, and business. It combines qualitative approaches with quantitative data and focuses on cases instead of variables, allowing for both in-depth analysis and comparisons (Raging, 1987). In contrast to most quantitative approaches, it can be applied both to large and small numbers of observations (see e.g. Schneider and Wagemann 2012). Accordingly, the second research question is stated as follows: *Which best practices can be identified and what do they imply for future research policy and funding approaches in single countries and at the European level?*

The availability of internationally comparable data on funding agencies and of a framework for categorizing them is highly relevant for both policy makers and the funding agencies themselves, as it paves the way for a better understanding of single agencies and their position within a broader international context. The identification of best practices takes such analyses one step further and allows for statements regarding the consequences of different funding approaches, the usefulness of reforms, and the potential for further improvement. Such insights are particularly relevant in the context of international funding. With the remarkable expansion of the European Framework Programs for Research and Development (EFP), a new important actor in funding systems has appeared at the supranational level (see e.g. Kuhlmann 2001, Nedeva 2013). The European Commission draws – among other things – on national experiences and best practices at national level to design its own funding schemes, to develop the framework programs further, and to define the future orientation of European science policy.

The remainder of the paper is structured as follows. Section two presents the theoretical background and discusses previous studies on funding agencies. It analyses previous classifications of funding agencies and suggests a novel approach for categorizing them. Section three introduces the empirical study by presenting and discussing the data collected. It applies cluster analysis to address the first research question and to identify different types of funding agencies. Section four addresses the second research question by explaining QCA as a method, discussing the performance indicator and the context factors considered, illustrating the calibration adopted, and presenting the results of the analysis. Chapter five discusses the findings of the study in a broader context, while chapter six concludes and proposes directions for further research.

2. Theoretical background and framework

2.1 Organization of public R&D funding

The way public research is financed varies considerably across countries. Research funding systems can be distinguished according to the relative importance of three main organizational models: institutional funding, project funding and vertical integration (Lepori et al. 2009, Millar and Senker 2000). Every model is characterized by different coordination modes between the government, the scientific community and, in some cases, intermediary organizations (see Lepori 2011). The main features of the three approaches can be described as follows:

- In the case of *institutional funding*, the state allocates a global budget to universities and other public research organizations to ensure their activities. Funding is not limited in time and – although a general service agreement with the government might exist – the organizations decide themselves on how to use the money.
- In the *project funding* mode, funding is allocated directly to the researchers and not to an institution. It is attributed based on the submission of a project proposal describing the research activities to be done and is limited in time and scope (Lepori et al. 2007a). Funding agencies play a central role in this mode as they are in charge of allocating a large part of project funding.
- In the *vertical integration* mode, a so-called “umbrella organization” with a generic research mandate receives a global budget that it internally allocates either as institutional funding or on a competitive basis (Lepori et al. 2009). Classic examples are public research organizations that conduct basic research outside universities, such as the National Center for Scientific Research in France (CNRS), or the Max Planck Society in Germany (MPG).

The three organizational models represent ideal types, but in reality, their boundaries are fuzzy and overlapping. Moreover, they are not mutually exclusive and may coexist within the same research funding system. Most European countries have both institutional and project funding, and some of them also feature vertically integrated funding modes. However, large differences exist in the relative importance of different organizational models. For example, the United States represent a typical case of a system strongly based on project funding, while Italy and Spain can be clearly assigned to the vertical integration mode. Other European countries such as the Netherlands, Norway, and Switzerland have a particularly high level of institutional funding (Lepori 2011).

As a consequence of reforms aimed at increasing competition among universities, the relative importance of different funding models has gradually changed in many countries, with project funding gaining importance at the expense of institutional funding of universities and other research organizations (Geuna 2001, Lepori et al. 2007a). At the same time, the rationales of scientific production have undergone considerable changes, shifting from a “Mode 1” to a “Mode 2” paradigm (Gibbson et al. 1994, Nowotny et al. 2001, 2003).

Under “Mode 1”, research funding was granted to both universities and scientists through “blind delegation” by the state (Braun 2003), with scientific quality being the main criterion for the allocation of funds within the scientific community (see also Rip 1994). By contrast, the “Mode 2” paradigm stressed the social relevance, applicability and accountability of science.

The emergence of “Mode 2” approaches to science policy has led to the need of coordinating policies in order to overcome the paradox of steering research towards societal and economic needs while granting researchers enough autonomy. In the case of institutional funding of universities and umbrella organizations, coordination has taken place through contracts in which the state and the universities agree upon the service portfolio to be delivered (Braun 2003). In the case of project funding, the share of funds directed towards more applied research has increased at the expense of investigator-driven grants (see also Gulbrandsen 2005), and new funding schemes promoting, for example, networks of scientists and users have appeared (Lepori 2011, Braun 2003). The importance of funding agencies has thus increased not only in terms of the amount of resources they allocate, but also with respect to their role as platforms for combining societally and economically relevant research with purely academic goals (Van der Meulen 2003).

2.2 Role and functioning of funding agencies

Funding agencies encompass different types of organizations and may be agencies in the strict sense, councils, academies, or foundations. The common feature is that they are created by the state and are in charge of allocating public R&D funds competitively (Reale et al. 2012). However, their role within the scientific system is far from restricted to the mere distribution of money. By setting the criteria for resource allocation, funding agencies significantly influence the behavior of scientists and contribute to constructing, reproducing, and changing the institutional order of academic research (Benner and Sandström 2000). They are often governed by boards composed of key stakeholders from the government, the scientific community, industry, and society, and may be in charge of implementing a part of research policy (Braun 2008). Recently, national funding agencies have also become important strategic actors in research and innovation governance at the European level, mediating between the national and the international level (Kuhlmann 2001 cited in Reale et al 2012).

Because of their role at the interface between policy and science, funding agencies have often been studied from the perspective of principal-agent theory (see for example Braun 1993, Guston 1996, van der Meulen 1998). Principal-agent theory is a widely used approach first developed in new institutional economics (Jensen and Meckling 1976, Pratt and Zeckhauser 1985) and then applied to many other fields of economics and business, sociology, and political science. It analyses interdependent relationships between two parties in which the first (the principal) assigns resources to the second (the agent) in order to perform some previously defined tasks. The agent possesses specific expertise that the principal lacks, and the ability of the principal to judge the work to be done is often limited (van der Meulen 1998). As the agent may have his own interests and pursue his own goals, which potentially conflict with those of the principal, the principal needs to monitor the activities of the agent and make sure that he fulfils his tasks correctly.[1]

Funding agencies are in multiple relationships with the state and the scientific community, and have been analyzed both as the agents (Braun 1993) and as the principals themselves (Guston 1996, Gulbrandsen 2005). In their relationship to the governments, funding agencies take the role of agents with the task of implementing policies according to the interests of policy-makers. However, depending on how close their boards are to the scientific community, the interests of researchers may predominate (see for example Clark 1983). In the "policy arena" (Braun 1998), where scientific boards and other policy committees define the strategy and program of the funding agency, goal conflicts between government representatives asking for more economically and socially relevant research and researchers advocating the autonomy of science may arise (Gulbrandsen 2005).

[1] Another important component of principal-agent relationships is trust. Though trust is often neglected in the principal-agent literature, it helps to create stability and continuity in long-term relations and multiple interactions (Shapiro 1987 cited in van der Meulen 1998).

In their relationship to the scientific community, funding agencies may take the role of principals. Researchers will see them as providers of funding and implementers of government policies through their choice of instruments, priority areas, and selection mechanisms (Slipersaeter et al. 2007).[2] Conflicts may arise in the "selection arena" (Braun 1998), where the best proposals are chosen according to their scientific quality and relevance.[3] Apart from adverse selection, that is, the risk of not choosing the right candidates for a project, there is a danger of moral hazard that needs to be addressed (Gulbrandsen 2005, Guston 1996). Researchers may adapt their proposals to match the requirements of specific calls even if their own goals do not completely match those of the funding agency. Consequently, they may not deliver the results that were initially agreed on, making a functioning monitoring and control system necessary.

A third approach views funding agencies as intermediary organizations between policy-makers as principals and the scientific community as agents (van der Meulen 1998, 2003). In this case, funding agencies represent a platform where the interests of the two groups can be formulated, and where coordination may be achieved. Policy-making within funding agencies is seen as an interaction process between scientists, administrators and politicians (Knorr-Cetina 1982, Rip 1988). In their role of intermediaries, funding agencies need to act as independent actors, maintaining a sufficient distance from both the government and the scientific community, and shaping the relationship between these two groups of stakeholders (Braun 1993, Guston 1996).[4]

Any funding agency may adopt all of these roles depending on the situation at hand, but the frequency and intensity with which they emerge vary considerably in different institutional settings. The principal-agent approach helps to understand policy outcomes

[2] However, many scholars still question the real influence of governments on funding agencies. Science policy has its limits, because loyalties towards the government are often mediated and modified by the necessary involvement of science (Slipersaeter et al. 2007). Political actors may influence distributive norms by formulating general policy ideas and guidelines, and by manipulating the general images guiding funding decisions. They may also set up an overall control system to enhance accountability (Braun 1998). However, they have only little influence on the program formulation and implementation at the operational level, on the selection process, and on the monitoring of research progress.

[3] While in a first step the scientific quality is usually evaluated by other scientists (peers) acting as reviewers, in a second step scientific and eventually political boards assess the relevance of the project proposals (Braun 1998).

[4] In a study on the divisions of the Research Council of Norway, van der Meulen (2003) identified three characteristics of particularly autonomous funding agencies, i.e. agencies that were able to implement their own strategies. First, they were especially oriented towards the users of research, i.e. industry or – in a broader sense – society. Second, they had extensive monitoring rights; and third, they were only accountable to one main ministry and not to several political actors.

resulting from the conflicting interests of government and researchers, such as the aim of funding more applied research or increased monitoring and reporting obligations. However, it does not say much about the consequences that these outcomes will have for research at universities. Depending on how close funding agencies are to the government or the scientific community, their funding schemes will vary, possibly affecting the research performance of universities.

2.3 Typologies of funding agencies and funding instruments

In order to investigate the implications of different funding approaches, one first needs to identify existing types of funding agencies. Previous literature has distinguished three main types of funding agencies that considerably differ in terms of their relationship to the government and to the scientific community, and their overall role in science policy (Braun 1998): science-based agencies, political funding agencies, and strategic funding agencies.

- *Science-based agencies* represent the traditional form of academic funding bodies, strongly identifying with the research performers, especially those working at universities. They feature a high degree of autonomy from the state, they are structured according to disciplines, and they represent the scientific community in national institutions, serving their interests (Skoie 1996). Selection and monitoring are organized as peer-review processes that are dominated by the researchers themselves (van der Meulen 2003).[5] Typical examples of such agencies are the German Research Foundation (DFG) or the Austrian Science Fund (FWF).
- By contrast, *political funding agencies* are characterized by a strong role of the government at both policy and operational level. These agencies serve the interests of a ministry, supporting applied research and development in close contact with users and government representatives (Scoie 1996). Although peers may be involved in the monitoring processes, the latter are primarily defined by the council as a

[5] This approach assures the scientific quality of the projects. However, such peer review and disciplinary orientation may also foster mainstream research by selecting and funding reputed scientists within a disciplinary tradition, hampering the promotion of innovative and path-breaking projects (Braun 1998). Similar problems may arise in the peer review process of academic journals (for further critical discussions see e.g. Bedeian 2004, Tsang and Frey 2007).

"lieutenant of the government" (van der Meulen 2003).[6] Examples of such political agencies are the Finnish Funding Agency for Technology and Innovation (Tekes) or the Commission for Technology and Innovation in Switzerland.

- Finally, *strategic funding agencies*, or so-called mission-agencies, are set up to promote research in specific areas of public interest, such as medicine, agriculture, or energy. They promote and eventually execute basic research while improving the transfer of basic knowledge and its application outside academia (Braun 1993). Examples of such agencies are the UK research councils and the National Institutes of Health in the US.[7]

With the recent reforms and the widening of the scope of many funding agencies, the distinctions between these three ideal types have become increasingly blurred. Especially scientific funding agencies have acquired new political tasks such as addressing governmental priorities and industry needs, and inducing more structural changes in the research base by means of research centers and large, long-term funding schemes (van der Meulen 2003). As the extent to which funding agencies have been affected by these changes differs considerably across countries, a more detailed differentiation is necessary.

The status of funding agencies, their degree of autonomy from the state, and their mission directly translate into their operational tasks and the types of funding instruments they use (see also Slipersaeter et al. 2007). An obvious approach to categorizing and comparing funding agencies is thus to analyze the relative importance of their different types of funding instruments and to identify their *funding profile*. To do this, one needs to differentiate funding instruments according to those dimensions that best reflect the status of funding agencies and their mission.

One first important dimension is the tension between bottom-up and top-down research funding. The former, also called responsive-mode funding, comprehends free, curiosity-driven projects that are initiated by the investigator. The latter is related to the

[6] Political agencies often need to create hybrid communities in order to address politically defined problems and may thus give an opportunity to upcoming and innovative scientists to build up their own reputation (Braun 1998). At the same time, such innovative projects are also highly risky and political agencies are often forced to find a mix of conventional and innovative investigators.

[7] According to Braun (1998), strategic funding agencies combine both established scientists and more unconventional researchers, and may foster both settled disciplines and new, emerging fields. Although resource appropriation for idiosyncratic purposes remains a strong tendency, the author argues that these agencies offer the best opportunity to successfully combine both political and scientific interests in funding.

concept of thematic funding (Lepori et al. 2007b) and describes projects where topics and goals are largely defined in advance by the funding agency and – indirectly – by the government.[8] Top-down funding is allocated by means of temporary calls that describe more or less in detail the goals of the project and may include additional requirements such as the involvement of external partners from other universities, from business and society, or from abroad.[9] Although bottom-up and top-down processes are not mutually exclusive (van der Meulen 1998), this dimension is crucial for the characterization of funding agencies.[10]

A second relevant dimension concerns the scale of funding. Apart from single projects, funding agencies may promote extensive programs with the aim of building up long lasting structures within a national research system (OECD 2014, Orr et al. 2011). Among other things, the goal of such programs is to foster excellent research and thematic focuses within single universities or groups of universities and research institutions, establishing a critical mass of researchers, infrastructure, and financial resources to ensure their high visibility at national and international level. As opposed to single projects, high amounts of funding are assigned to relatively few research groups for a significantly longer period of time that may last up to 10 or 12 years (see e.g. Aksnes et al. 2012, Braun and Benninghoff 2003).[11] Examples of such networks are the German Excellence Initiative, the National Centers of Competence in Research in Switzerland, and the Centers of Excellence funded by the Danish National Research Foundation (DNRF).

[8] The separation of bottom-up and top-down funding partly reflects the traditional tension between fundamental and applied research (Gulbrandsen 2005). While this tension is of central importance for distinguishing science-based and political agencies, it is less crucial for the present study. The increasing focus of these agencies on user-inspired research is better captured by the concept of top-down funding than applied research, which describes a type of research that mainly takes place outside the classic universities. Moreover, the difference between basic and applied research is not always as clear as the terminology might suggest (for a semantic discussion of the concept of basic research see Schauz 2014). A clear distinction is thus rarely possible, especially within universities.

[9] The idea of bottom-up and top-down funding is closely related to the concept of aggregation and steering, with aggregation meaning institutionalized processes of agenda-building and decision-making involving the scientific community, and steering indicating the attempts of the state to get scientists to work towards state goals (Rip and van der Meulen 1996).

[10] When we compare the main funding institutions of Norway and Switzerland, it becomes clear that the relative importance of bottom-up and top-down research varies a lot among academic funding agencies in Europe. The Norwegian Research Council allocates less than 20 percent of funds as grants and free projects, while the Swiss National Science Foundation allocates about 80 percent of its funding through responsive-mode instruments (Slipersaeter et al. 2007).

[11] While research topics might be inspired by societal or economic challenges, the focus of the programs remains basic research at the technological frontier and the achievement of world-class academic excellence. Because of the high amount of resources involved and their importance for the national research system as a whole, representatives from the government are often involved in the definition of the broad characteristics of the programs and in the final approval of the beneficiaries selected by the scientific committees (see e.g. Kehm and Pasternack 2008).

Finally, an important dimension of academic funding agencies centers on the difference between fellowships for young talents and grants for specific projects. Funding agencies are not only in charge of funding research projects, but also of securing future generations of researchers and thus promoting individuals at different stages of their careers, including PhD students, postdocs, assistant professors, and full professors (van Arensberger et al. 2014). Usually, such fellowships include the description of planned research projects, whose scientific quality is assessed by peer reviewers. As opposed to project grants, however, the group of potential applicants is very limited and does not include leading scholars. While most fellowships are not restricted to specific topics and proposals may be submitted in a bottom-up process, previous publication performance and awards are still among the main criteria for grant allocation (van Arensbergen et al. 2014).

Table 1 summarizes the dimensions of funding instruments identified, their main categories and characteristics. As every category of instruments has its own rationales and requirements, it should affect the research performance of individuals, groups of scientists, and whole universities in different ways (Potì and Reale 2007). For instance, bottom-up projects mainly serve academic goals and are thus expected to foster scientific productivity in terms of publications and citations more than top-down projects. These differences are probably less pronounced in the other dimensions, as they all primarily serve academic goals. One could argue that large programs may foster publications and citations more than single projects because they provide a critical mass for excellent research and the opportunity to profit from synergy effects (Orr et al. 2011). Similarly, project grants for established researchers may be related to higher research performance than fellowships because scientists selected for funding have a higher standing and may achieve better publications. On the other hand, young researchers that have been granted a fellowship may be more productive because of the need to publish in journals with high impact factors to advance their academic career.

Table 1: Dimensions of funding instruments, their characteristics, and possible effects on research performance

Dimension	Category	Characteristics	Effects
Thematic orientation	Bottom-up calls	Researchers are free to define the content and goals of the projects.	Strong effect on academic performance of single researchers, less transfer of results to business or society.
	Top-down calls	The goals are defined in advance to varying degrees of detail.	Higher transfer of the results but eventually lower effect on academic performance.
Structural orientation	Single projects	Only one researcher or research group is funded for a rather short time period.	Funded researchers may profit but there are not many synergy effects.
	Large programs	Funding is granted to larger networks and for a longer time period.	Scale and synergy effects may lead to higher academic impact.
Talent orientation	Project grants	The quality and relevance of the project is the only rationale for funding allocation.	Funding is granted to established and reputed scholars. High probability of major academic impact.
	Fellowships	Promotion of young talents at different stages of their career is an important aim of funding.	Funding is granted to young talents and serves their career advancement. Major academic impact is less certain.

3. Categorization of funding agencies in Europe

3.1 Sample definition and data collection

The present study aims at identifying best practices among funding agencies in terms of their ability to foster university research. For this reason, it only focuses on those agencies that primarily grant funding to university researchers and thus contribute to their academic work. Purely political agencies fostering applied research and innovation, and granting funding to researchers outside universities, are not included. Similarly, “umbrella organizations” such as the French CNRS and the German MPG are also excluded. Though these organizations may collaborate with universities, their main task is not to allocate competitive grants and they do not significantly shape the activities of university researchers.

From a geographic point of view, the analysis is restricted to countries in Western and Northern Europe. The selected countries have all well-developed scientific systems and rather similar macroeconomic context factors. Although common research policies have been developed at European level, every country has its own funding system, which may considerably differ from those of other states (see e.g. Lepori et al. 2007a). Apart from very small countries with less than one million inhabitants, most governments have set up at least one or two funding agencies that are included in the analysis. The only exceptions are Italy, Spain and Greece, where research funding is directly allocated either to universities or to large “umbrella organizations”, namely the National Research Council in Italy (CNR), the Spanish National Research Council (CSIC), and the National Hellenic Research Foundation (NHRF). This left us with 25 funding agencies from 13 countries and one supranational organization, the European Union.[12]

An in-depth analysis of funding agencies requires information about their operational and administrative resources, their different types of funding instruments, and the funding process itself. Collecting such comparative data on all funding agencies posed several challenges because data processing methods and reporting practices considerably differ across countries.

To ensure comparability of the data collected, a two-step procedure was chosen. First, all publicly available information that could be found in annual reports, yearly accounts, information brochures, and websites of the agencies was collected and analyzed. In a second step, every agency was contacted and requested to clarify potential ambiguities and questions regarding the data already collected, and/or to provide additional information where data was missing. Most enquiries involved several attempts and repeated interactions. Moreover,

[12] We included two funding agencies in charge of allocating grants within the European Framework Programs for Research: the European Research Council (ERC) and the Research Executive Agency (REA). Both the ERC and the REA grant a large share of their funding to university researchers. In contrast, many EU programs for applied research and programs that do not primarily focus on university research are managed either by the Directorate General or by other Executive Agencies, such as the Executive Agency for Small and Medium-size Enterprises (EASME) and the Innovation and Networks Executive Agency (INEA).

the funding agencies could not provide all information requested, either because they were not allowed to hand out the data or because they did not collect it at all. Nevertheless, the combination of desk research and targeted enquiries resulted in a rich dataset that allows for significant analyses and conclusions.

3.2 Descriptive results

Table 2 presents the funding agencies included in the analysis with their full English name and the current acronym, which is usually based on the national language. To provide an overall picture of the agencies, figures on total expenditures, their growth between 2009 and 2013, and funding allocations per person are also displayed.[13] Appendix 1 includes more detailed figures on the structure of the agencies, such as their administrative costs, and the number of personnel employed in their offices. Appendix 2 presents figures concerning the selection and funding processes, namely the number of yearly submissions, the number of projects granted, the acceptance rate, and the amount of money per project.

First of all, substantial differences in the size of the agencies as measured by their budget stand out. The largest single funding agency is the German DFG with almost 2.7 billion Euro expenditures, while taken together, the UK Research Councils have a budget of almost 4.2 billion Euro.[14] However, the size of the countries and their research system also differ significantly. In relation to the countries' population, funding agencies are particularly large in Norway, Sweden and Switzerland, while they are comparatively small in Austria, Belgium, France, and Germany (see appendix 1).

[13] The year 2009 has been chosen as a reference point in order to exclude possible effects of the financial crisis in 2008, and because in many cases earlier data was not available. In many countries, a considerable increase in the budgets of the funding agencies had already taken place earlier, reflecting the growing importance of project funding.

[14] The overall budget of the UK Research Councils also includes own research laboratories and facilities, which are particularly important for the MRC, the NERC, and the STFC.

Table 2: Indicators for expenditures and personnel of European research funding agencies (2013)

Country	Agency	Acronym	Total expenses	Growth 2009-2013	Funding per FTE
Austria	Austrian Science Fund	FWF	231.2	4.4	2.6
Belgium	Fund for Scientific Research	FNRS	168.1	-0.8	2.7*
Belgium	Research Foundation - Flanders	FWO	226.4	7.2	4.4
Denmark	Danish National Research Foundation	DNRF	58.9	40.3	6.3*
Denmark	Danish Council for Independent Research	DFF	163.8*	-3.0*	4.1*
France	French National Research Agency	ANR	596.0	-31.4	2.6
Germany	German Research Foundation	DFG	2692.1	10.1	4.0
EU	Research Executive Agency	REA	1439.8	106.7	2.6
EU	European Research Council	ERC	1762.5	89.3	4.5
Finland	Academy of Finland	AKA	338.6	18.7	2.4
Ireland	Science Foundation Ireland	SFI	161.7	-13.7	3.2
Netherlands	Netherlands Org. for Scientific Research	NWO	735.2	10.0	1.5
Norway	Research Council of Norway	RCN	933.2	13.1	1.9
Portugal	Foundation for Science and Technology	FTC	436.0	-13.6	1.7*
Sweden	Swedish Research Council	SRC	698.8	55.9	3.9
Sweden	Swedish Foundation for Strategic Research	SSF	133.2	113.4	8.7
Switzerland	Swiss National Science Foundation	SNSF	780.3	57.4	3.9
UK	Arts and Humanities Research Council	AHRC	129.1	-9.6	1.5
UK	Biotechnology and Biological Sciences RC	BBSRC	610.5	-4.6	2.4
UK	Engineering and Physical Sciences RC	EPSRC	1020.4	-7.9	4.4
UK	Economic and Social Research Council	ESRC	262.5	-2.8	1.8
UK	Medical Research Council	MRC	1026.6	-3.0	0.2
UK	Natural Environment Research Council	NERC	517.4	-1.7	0.1
UK	Science and Technology Facilities RC	STFC	615.0	-23.4	0.2
Total/Mean			**15’737.2**	**14.2**	

* Estimate or approximation.
Total expenses are in million Euro. Total expenses include both funding allocations and administrative expenses. Funding per full-time equivalent (FTE) includes only funding allocations. Growth 2009-2013 refers to real growth (2013 prices).
The Irish Research Council (IRC) is not included in this overview because it could not provide figures on the personnel and the administrative costs of its office. With a total of 34 million Euro of funding allocations in 2013, the IRC is the smallest funding agency included in the analysis.

With respect to the change of expenditures between 2009 and 2013, we note that the budgets of funding agencies have increased by 14.2 percent on average. At the same time, different evolution patterns can be observed for single countries. While in Sweden and Switzerland the funding agencies' budgets have considerably increased, in Ireland, Portugal, and the UK they have stagnated or slightly decreased. Moreover, the significant increase of funding at EU level stands out, as does the considerable reduction of the budget of the ANR in France.[15]

The amount of funding per personnel also differs considerably among agencies and already hints at their main funding schemes. Funding per person will be lower if agencies fund numerous projects with rather small amounts, and higher if fewer but larger projects are funded. For example, the ERC, which allocates up to 2.5 million Euro per grant through its highly competitive Advanced Grants scheme, has a funding per personnel ratio which is almost twice as high as the one of the REA. Moreover, projects and grants in the natural and technical sciences are usually larger than in the social sciences and humanities, as they account for expensive laboratory equipment (Lin et al. 2014). It is thus not surprising that among the UK Research Councils, the BBSRC and the EPSRC display a higher funding per FTE than the AHRC and the ESRC. On the other hand, the very low funding per FTE displayed by the MRC, the NERC, and the STFC is due to the many research institutes and facilities belonging to these Research Councils and, consequently, their number of personnel being much higher than that of other funding agencies.

As shown in appendix 1, administrative costs make up between 2.3 and 8.1 per cent of total expenditures. However, even though funding agencies often present them as performance indicators, these figures are hardly comparable. First, as no common approaches or guidelines exist at international level, every agency assesses its administrative costs autonomously using different parameters and including different items.[16] Second, as in

[15] Public research funding in France was dominated for a long time by the CNRS as a typical large umbrella organization. The ANR was only created in 2005 and initially saw its yearly budget increase up to about 850 million Euro in 2008 (ANR 2009). However, from 2009 onwards a considerable downscaling took place in the wake of the financial crisis and a repositioning of the ANR in the context of a new innovation strategy that aimed at a stronger coordination between national and international funding (Ministry of Higher Education and Research 2013).

[16] Salaries of the personnel employed in the offices of the agencies are the main component of administrative expenditures, making up more than 50 percent of costs. Other items, such as board members remuneration, travel expenses, building occupancy expenses, or reviewer fees, differ considerably and are not equally considered by all funding agencies.

the case of funding per personnel, the percentage of administrative expenses strongly depends on the funding instruments and the average amount of funding granted per project.

Another common performance indicator for funding agencies is the acceptance rate of project proposals (see appendix 2). Most acceptance rates lie between 15 percent and 30 percent, with a few exceptions. While agencies that primarily manage large excellence grants, such as the DNRF and the ERC, display low acceptance rates of about 10 percent, the Belgian FNRS and the Swiss National Science Foundation have acceptance rates of 36 percent and 52 percent, respectively. Overall, acceptance rates have decreased between 2009 and 2013, indicating that competition for grants is growing. The most remarkable decrease in acceptance rates has occurred in Austria, Belgium (FWO), France, Finland, and at the EU level (REA).

Finally, appendix 2 confirms that funding per project – as already mentioned – differs considerably among agencies and strongly depends on their funding instruments. As expected, the DNRF and the ERC feature a particularly high level of funding per project. In contrast, traditional academic agencies that focus on smaller projects and fellowships for PhD students and postdoc researchers have a rather small amount of funding per project. Finally, in several countries and at European level funding per project has increased between 2009 and 2013, indicating that many agencies are moving away from their traditional tasks towards fewer, but larger grants.

3.3. Categories of funding agencies

In order to categorize funding agencies, information on the relative importance of their different funding schemes – as measured by their share to total funding allocations – was collected. For most agencies, these figures referred to the amount of funding *allocated* during 2013. Where such figures were not available, the amount of funding *granted* in the same year was used.[17] The single funding schemes were then assigned to the four categories

[17] The amount of funding *allocated* in a given year is a better indicator for the overall orientation of an agency because it is less subject to yearly variations. For instance, calls for large, multi-year programs do not always take place on a yearly basis and might thus be under- or overrepresented if *granted* funding is used as indicator. To assess whether granted funding was a reliable measure it was necessary to control whether the figures were stable over the last five years.

representing the dimensions previously described, namely fellowships, bottom-up projects, bottom-up programs, and thematic or top-down instruments.[18]

Table 3 presents the resulting share of the four types of instruments to total funding allocations, while the category “other” comprehends all funding schemes that could not be attributed to any of the four dimensions.[19] Appendix 3 lists the absolute figures as expressed in million Euro.

Groups of universities with similar funding profiles were identified using hierarchical cluster analysis (see for example Everitt et al. 2011, Mooi and Sarstedt 2011). Hierarchical clustering is usually preferred to other widespread methods when the sample size is small and the number of clusters is not defined in advance (for a similar application to universities see Seeber et al. 2015). The commonly used agglomerative approach starts by treating each observation as a separate cluster. The algorithm then merges the two most similar clusters and links them at the next level of the hierarchy. It repeats this procedure stepwise until only one cluster is left. The resulting sequences can be represented graphically as an evolutionary tree called dendogram that is used to identify the main clusters of interest.

[18] Top-down projects and programs were included in the same category, as they could not always be clearly separated from each other and only very few instruments were unambiguously identified as top-down programs.

[19] On the one hand, these were smaller contributions not directly related to research projects, such as small grants for the organization of conferences and workshops, or for covering publication costs. On the other hand, the category also covers contributions for the acquisition of expensive equipment or for common infrastructures, including laboratories and facilities belonging to the agency itself. The latter types of expenditures often make up a larger part of funding allocations and explain the relative importance of the category “other” for agencies such as the NWO, the RCN, and most UK Research Councils.

Table 3: Categories of funding instruments of academic research funding agencies (in percent of total funding allocated or granted, year 2013)

Country	Agency	Fellowships	Projects	Programs	Thematic	Other
Austria	FWF	35.2	48.5	4.4	3.0	8.9
Belgium	FNRS	72.6	21.4	0.0	0.0	6.0
Belgium	FWO	47.0	51.0	0.0	0.0	2.0
Denmark	DNRF	3.2	0.0	87.0	9.8	0.0
Denmark	DFF	42.8	54.1	0.0	0.0	3.1
France	ANR	11.5	36.6	0.0	51.9	0.0
Germany	DFG	10.0	28.4	43.0	9.3	9.3
EU	REA	64.7	0.0	0.0	35.2	0.0
EU	ERC	62.4	29.5	1.3	6.8	0.0
Finland	AKA	19.9	40.7	14.6	7.3	17.5
Ireland	SFI	29.7	11.5	0.0	51.1	10.8
Ireland	IRC	72.7	2.9	0.0	24.5	0.0
Netherlands	NWO	27.8	20.8	0.0	11.5	40.0
Norway	RCN	0.0	11.8	0.0	59.1	29.1
Portugal	FTC	45.6	24.6	0.0	8.8	21.0
Sweden	SRC	8.7	47.7	12.6	0.0	31.0
Sweden	SSF	21.7	0.0	0.0	77.9	0.3
Switzerland	SNSF	21.5	50.0	13.8	8.1	6.6
UK	AHRC	41.3	31.0	0.0	21.0	5.4
UK	BBSRC	10.8	32.8	0.0	10.4	46.0
UK	ESRC	24.9	18.6	0.0	24.5	32.0
UK	MRC	8.3	17.7	19.0	6.9	48.0
UK	NERC	7.0	16.1	0.0	19.3	57.6

Two of the seven UK Research Councils were not included in the overview and the subsequent analysis. The EPSC could provide neither figures nor an estimate of the share of bottom-up grants to total grants. The STFC differs too much from the other funding agencies as it focuses on the provision of infrastructures and facilities. Consequently, most of its funding allocations had to be assigned to the category “other”.

The majority of hierarchical cluster analyses draw on the Euclidean distance measure to assess how similar, or different, the single observations are. The Euclidean distance measure can be interpreted as the physical distance between two points representing the observations in Euclidean space (Everitt et al. 2011) and is computed using the following formula:

$$d_{ij} = \left[\sum_{k=1}^{p}\left(x_{ik} - x_{jk}\right)^2\right]^{1/2}$$

where x_{ik} and x_{jk} are the kth variable value of the observation units i and j. In the present study, the shares of the four categories of funding instruments to total funding allocations – excluding those in the category “other” – served as variables. The distance between clusters with more than one observation was computed using Ward’s (1963) agglomerative approach, which is recommended if data is not influenced by outliers and equally sized clusters are to be expected (Mooi and Sarstedt 2011). At each stage of the merging process, Ward’s method minimizes the increase in the total within-cluster error sum of squares, which is given by

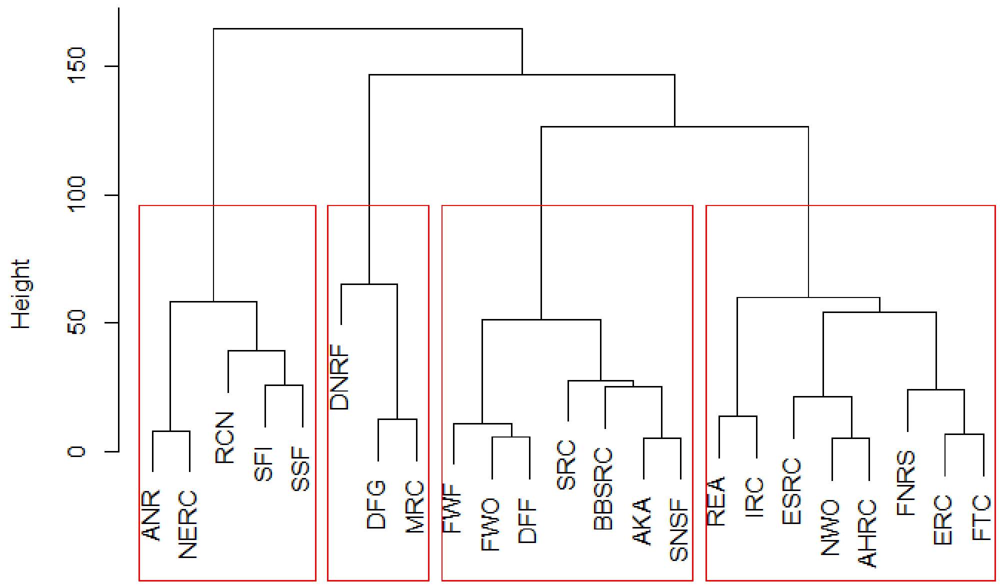
$$E = \sum_{m=1}^{g} E_m = \sum_{m=1}^{g}\left(\sum_{l=1}^{n_m}\sum_{k=1}^{p_k}\left(x_{ml,k} - \bar{x}_{m,k}\right)^2\right)$$

where $\bar{x}_{m,k} = (1/n_m)\sum_{l=1}^{n_m} x_{ml,k}$ is the mean of the mth cluster for the kth variable and $x_{ml,k}$ is the score of the kth variable of the lth observation unit in the mth cluster (Everitt et al. 2011).

Hierarchical cluster analysis suffers from two important limitations, namely high sensitivity to outliers and dropped observations, and the inability to modify poor cluster assignments in later steps (because once an observation is assigned to a cluster it will not change its position). To test the stability of the results, Ketchen and Shook (1996) suggest a two-step procedure. In a first step, hierarchical cluster analysis is applied to identify a reasonable number of clusters. This number is then used in a second analysis based on a nonhierarchical approach such as the k-mean procedure. In the present case, the analysis based on the k-mean procedure identified the same clusters as the one based on Ward's agglomerative approach.[20]

Figure 1 shows the dendogram of the hierarchical cluster analysis computed using Ward's method.[21] As shown by the red cases, four clusters of agencies with similar funding profiles could be identified. Appendix 4 and 5 present the groups of agencies graphically by plotting the share of different types of instruments in a three-dimensional diagram.[22]

Figure 1: Categorization of funding profiles of agencies: hierarchical cluster dendogram (based on Euclidean distance function and Ward's method)



The first cluster comprehends the ANR (France), the NERC (UK), the RCN (Norway), the SFI (Ireland), and the SSF (Sweden). These agencies have a rather strong focus on thematic funding, with top-down grants accounting for more than 40 percent of

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[20] Other common algorithms for agglomerative clustering, such as complete linkage, average linkage, and the centroid method, also delivered similar clusters.

[21] The statistical analysis, figures, and graphs in this paper have been computed using the statistical software R (R Core Team 2014).

[22] Appendix 4 includes the share of fellowships, while appendix 5 includes the share of bottom-up projects. As the clusters have been computed using all four variables, the two graphs need to be considered together.

total funding allocations. Though all of them also fund free research through fellowships and/or traditional project grants, thematic funding plays a dominant role.

The second cluster only includes three agencies, namely the DNRF (Denmark), the DFG (Germany) and the MRC (UK). This group of agencies is characterized by a particularly high share of large-scale and long-term bottom-up programs. Especially the DNRF focuses almost exclusively on the creation of Centers of Excellence that receive from 5 to 15 million Euro over a period of 10 years (DNRF 2010). The DFG has a rather mixed funding profile but displays a much higher share of bottom-up programs than other funding agencies due to the implementation of the German Excellence Initiative (DFG 2015).

The third cluster represents a large group of agencies that allocate half of their funding or more through the traditional form of bottom-up project grants. Most of these agencies have a mixed funding profile. For instance, the AKA (Finland) and the SNSF (Switzerland) display funding instruments from every category, while the other agencies in the group feature significant shares of one other type of funding. Nevertheless, agencies in this group can be referred to as classic project-oriented funding agencies.

Finally, the fourth cluster comprises those agencies that feature a particularly high share of fellowships. This group is composed of the two European agencies (REA and ERC), the IRC (Ireland), the FNRS (Wallonia region of Belgium), the FTC (Portugal) and others. The Research Executive Agency (REA) displays a high share of fellowships because it is in charge of the Marie Curie program of the EU, besides the Future and Emerging Technologies program and a series of other thematic grants.[23] Several agencies in this group, such as the Dutch NWO and the two UK Research Councils AHRC and ESRC, also have a significant share of thematic grants and programs that make up about 20 to 30 percent of funding.

[23] These include Space Research, Sustainable Resources for Food Security and Growth, Inclusive, Innovative and Reflective Societies, Safeguarding Secure Society, Spreading Excellence, Widening Participation, Science with and for Society.

4. Identification of best practices

Identifying best practices among funding agencies is a very complex undertaking. Ideally, an in-depth analysis would require a direct link between the allocation of funding and the research output it produced. Although some agencies have started collecting data on publications or patents achieved through their funding (see e.g. DNRF 2014, MRC 2014), these data are far from complete and cannot be compared internationally.[24] Moreover, one needs to be aware of the complexity of the research and publication process, in which different funding streams often overlap, making a clear attribution of research output to a specific funding source often impossible (Langfeldt et al. 2015). Rather than being a simple input that leads to an output, external funding contributes to a more general process that eventually produces, among other things, papers and citations (Rigby 2011).

Another problem for the identification of best practices is that context factors affecting the activities of funding agencies differ considerably from country to country. As already discussed, Germany or France feature large public research organizations outside the university sector, while for example Portugal has a lower GDP per capita than most other countries in the sample and thus arguably fewer public resources for higher education and research. Depending on these context factors, the role of funding agencies may vary and different funding approaches may prove more appropriate.

To address these issues, the present study investigates best practices at country level, including the different funding approaches of agencies as one system feature among others. In those countries with more than one agency in charge of funding university research, the amount of funding in the different categories was summed up to create an overall funding profile for the country. Moreover, the analysis also accounts for those cases without a national funding agency by including Italy, Spain, and Greece. Consequently, a total of 16 countries was examined.

[24] Another option would be to rely on funding and grants acknowledgements in Thomson Reuter's Web of Science publication database. The practice of acknowledging funding sources has been introduced by Thomson Reuter's in 2009 (see e.g. Rigby 2011) but is still subject to several biases. Funding acknowledgements are only present in a part of publications and considerably vary depending, among other things, on the scientific field, the journal type, or the authors' country of origin (see e.g. Costas and van Leeuwen 2012, Díaz-Faes and Bordons 2014).

4.1 QCA

In order to investigate best practices at country level the present study applies Qualitative Comparative Analysis (Raging 1987, 2000, 2008). QCA originates from the social and political sciences, but has been increasingly applied in organization, management, and innovation studies in recent years (see for example Fiss 2011, Misangyi and Acharya 2014, Meuer et al. 2015). It fundamentally differs from standard statistical and econometric methods such as regression because it focuses on cases and set-theoretic relationships instead of variables (Raging 1987). In a first step, QCA assigns every case to different theoretically relevant sets, for example to the set of countries with a thematic-oriented funding agency. In a second step, it assesses necessity and sufficiency relationships between a condition or a combination of conditions, i.e. the inclusion or exclusion in one or more sets, and an outcome through the examination of subset-relationships (see e.g. Misangyi and Acharya 2014, Fiss 2007).[25]

QCA has two important features that make it an appropriate method for this study. First, it can be applied to both a small and a large number of cases (Raging 1987). Second, it allows for more than one combination of conditions to lead to the outcome of interest. This is the idea of "multiple causality" (Raging 1987, 2000, 2008) or "equifinality", which states that "a system can reach the same final state from different initial conditions and by a variety of different paths" (Katz and Kahn 1978 cited in Fiss 2011, p. 394). This is particularly important for the identification of best practices at country level, as – depending on the context in which funding agencies act – there might be different approaches that lead to the desired outcome.[26]

Two approaches to QCA have been widely applied in the literature: crispy-set and fuzzy-set QCA (see e.g. Rihoux and Raging 2009). The first approach only measures membership and non-membership in different sets, which it records using 1 and 0. The

[25] A condition is necessary if the set of cases with the outcome is a subset of the cases with the condition, because all cases that feature the outcome need to feature the condition. By contrast, a condition is sufficient if the set of cases with the condition is a subset of the set of cases with the outcome, as the presence of the condition automatically leads to the outcome.

[26] Moreover, QCA accounts for "causal asymmetry" (Raging 2008), i.e. the fact that the absence of a condition has not necessarily the opposite effect of its presence. As Fiss (2011: 394) points out, "the causes leading to the presence of an outcome of interest may be quite different from those leading to the absence of the outcome".

second approach is more nuanced and allows for different degrees of membership in each set. In fuzzy-set QCA, the data needs to be calibrated in order to assess to what extent a specific case is included in a given set. Calibration results in membership scores between zero and one, with zero indicating total exclusion from the set, one indicating total inclusion, and 0.5 representing the crossover point, i.e. the point of maximum ambiguity. Because most measures in the present study are continuous and a clear distinction of membership and non-membership is not always possible, fuzzy-set QCA is used to identify best practices.

Finally, QCA assesses the relevance of sufficient conditions using consistency and coverage measures as its two parameters of fit (see e.g. Schneider and Wagemann 2012). Consistency measures the proportion of cases that display both the conditions and the outcome, and thus describes the extent to which a causal combination leads to the outcome. Coverage, on the other hand, describes how many cases with the outcome also feature the condition of interest (Elliott 2013). While consistency fulfills a similar function to the parameters of significance in regression analysis, coverage can be compared to a parameter of strength such as the correlation coefficients and the total variance explained (Bara 2015).[27] Appendix 6 briefly describes how fuzzy-set QCA works and how consistency and coverage measures are calculated.

4.2. Sets and membership scores

Continuous variables can be calibrated and transformed into fuzzy-set membership scores by a piecewise logistic function (Thiem and Duşa 2012). This procedure implies the definition of the two thresholds for full exclusion and full inclusion, as well as the crossover point by theoretical considerations and expert knowledge (Raging 2000).

The sets relating to the types of funding agencies in a country were calibrated according to the values of the observations in the four clusters previously identified. For the sets of countries with *project- and fellowship-oriented agencies*, the threshold for full inclusion was set at 70 percent, which roughly corresponds to the maximum values among

[27] QCA may also compute consistency and coverage measures with respect to the necessity of conditions. However, the aim of this study is to identify those combinations of conditions that leads to the outcome of interest, focusing on sufficiency rather than necessity.

the agencies in the corresponding clusters. The threshold for full exclusion was set at zero and the crossover point midway at 35 percent. In doing so, all agencies in the two groups were identified as more in than out of the relevant set.[28]

For the sets of *program- and thematic-oriented agencies*, a slightly lower threshold of full inclusion at 50 percent was used. As opposed to bottom-up projects and fellowships, which are traditional funding schemes that almost all agencies feature, large programs and thematic funding represent an additional focus of the agencies and account only for part of the funding allocations. With a threshold for full exclusion at zero and the crossover-point midway at 25 percent, all agencies in the corresponding clusters were identified as more in than out of the sets.[29]

In order to identify best practices for funding agencies, it is necessary to measure the success of a whole higher education system in terms of research at public universities. To this end, an indicator based on the *share of students at internationally highly reputed universities* was constructed.[30] The Academic Ranking of World Universities (ARWU, also known as Shanghai ranking), which is primarily based on research outputs (Marginson 2006), served as a measure for the international reputation of universities. An institution was defined to be very successful if it was listed among the 200 best universities according to the ARWU. In total, 78 European universities belonged to this group in 2013, allowing for enough differentiation among single countries.[31]

The student numbers of the top 200 universities in each country were summed up and divided by the total number of students in the corresponding country.[32] This procedure led to values ranging from zero percent in Greece, Ireland, Portugal and Spain, where no top 200 universities existed in 2013, to 36.7% in Switzerland. In order to calibrate the indicator

[28] With a threshold at 70 percent, full inclusion was only possible if one of the two funding schemes clearly dominated all others. In the case of fellowships, Belgium and Portugal proved almost fully in the set, while in the case of project funding, Austria, Sweden, Switzerland, and the UK had membership scores of 0.8 or higher.

[29] In the case of program-oriented agencies, Germany proved almost fully in the set, while for thematic-oriented agencies this was the case for France, Ireland, and Norway.

[30] By normalizing for the number of students of a country instead of its population, this measures accounts for the fact that different countries have very different education systems and different university enrolment rates (OECD 2015).

[31] As US universities dominate the highest positions of the ranking, a threshold at top 200 represents a reasonable compromise between too tight a selection and too broad a widening.

[32] In some countries, such as Austria, Germany and Switzerland, universities of applied sciences exist, which focus more on education and applied research. One could argue that the above-mentioned measure should not account for students of these universities. However, universities of applied sciences increasingly attract research funds and their students are thus included in the assessment of the performance of the countries' higher education systems.

into membership scores, Switzerland served as a benchmark, implying a threshold for full inclusion at 36.7. The threshold for full exclusion was set at zero and the crossover point midway at 18.35. Countries that were more in than out of the set of successful university systems were Austria, Belgium, the Netherlands, and Sweden, with membership scores ranging from about 0.6 to 0.8, while Germany and the UK had a membership score close to 0.5.

In order to account for the national context of funding agencies, the analysis included four context factors that may affect the research performance of universities. First, abundant resources are a key condition for successful research universities (see e.g. Lin et al. 2014, Salmi 2009, 2011). In countries with an overall high level of resources, as measured by *GDP per capita*, universities may be able to invest more into research. In order to calibrate the measure into membership scores, the average GDP per capita of the European Union, USD 35’000, was used as crossover point. The thresholds of full inclusion and full exclusion were set at 50’000 USD and 20’000 USD, respectively, i.e. about 40 percent above and below the average.[33]

Second, in countries that are more technology-oriented, universities may acquire more funds from both public and private sources. Cases were assigned to the set of technology-oriented countries according to their *share of research and development (R&D) expenditures to GDP*, which represents another key factor for the development of successful universities (see e.g. Aghion et al. 2008).[34] In its growth strategy Europe 2020, the European Commission set the target of investing 3 percent of GDP in R&D (European Commission, 2010). For this reason, we chose 3 percent as the threshold of full inclusion in the set of countries with high R&D expenditures. The threshold for full exclusion was set at 1 percent, and the crossover point at 2 percent.[35]

[33] Only Switzerland and Norway proved to be fully in the set of rich countries, with Austria, Ireland and the Netherlands in second place, reaching a score of about 0.8. Most other countries proved more in than out of the set, with only Greece, Italy, Portugal, and Spain scoring less than 0.5.

[34] Like GDP per capita, the share of R&D expenditures to GDP indicates the amount of resources that are potentially available for university research. The distinction is nevertheless important, as countries with above-average GDP and a very low share of R&D expenditures may provide insufficient funding for university research

[35] Five countries, namely, Austria, Germany, Finland, Sweden, and Switzerland, proved to be fully or almost fully in the set, displaying membership scores of 0.9 or higher. Except for Belgium and France, which reached a membership score of about 0.6, all other countries proved to be more out than in the set.

Third, as already noted, the share of public research conducted at universities considerably differs across countries, being lower in those with large public research organizations such as the CNRS in France or the MPG in Germany. For this reason, the analysis accounted for the share of public research spending within universities to the country's total public research spending. As expected, Germany and France scored rather lowly, with only about 50 percent of public research funding managed by universities. In contrast, in Denmark and Switzerland universities receive almost 90 percent of public research funding. Given these figures, the threshold for full inclusion was set at 80 percent, the threshold for full exclusion at 50 percent, and the crossover point midway at 65 percent.[36]

Finally, in order to assess best practices among funding agencies, it is necessary to account for their relative importance. In countries where universities receive most research funds through institutional funding, agencies that allocate research grants competitively will play a minor role. The analysis thus includes the share of their budget to total public research expenditures in universities. Although universities may also compete for other third party funds, funding agencies remain the main source of external funding. Their relative importance thus reflects the role of competitive grants within the research system. The UK proved to be the country with the highest share of competitive public research funding, with its Research Councils accounting for over 50 percent of university R&D expenditures. In contrast, in countries such as Austria, Denmark, and France, this figure only amounts to about 10 percent. Accordingly, the threshold for full inclusion was set at 50 percent and the one for full exclusion at 10 percent, with a crossover point at 30 percent.

The data on the performance measure and context factors is summarized in table 4, while the corresponding membership scores after calibration are presented in appendix 7. Figures on GDP per capita, total research expenditures of a country, and the public research expenditures within universities stem from the online database of the Organization for Economic Co-operation and Development (OECD). In the case of GDP per capita, the data is expressed in purchasing power parity (PPP) dollars to allow for comparison between countries.[37]

[36] Using these thresholds, only Denmark and Switzerland achieved full membership, and the Netherlands, Portugal and Sweden reached a score of about 0.8. In contrast, Germany and France, along with Austria, Greece, and Spain, scored very lowly.

[37] The full QCA analysis was computed using the package "QCA" (Dușa and Thiem 2014) for the statistical software R.

Table 4: Performance measure and context factors used in the analysis

Country	Top 200 students (percent)	GDP per capita (USD PPP)	Total R&D to GDP	HE share of public R&D	Agency to HE R&D
Austria	23.33	430380	2.81	56.18	11.62
Belgium	28.2	393366	2.28	60.85	29.27
Switzerland	36.7	525453	2.96	88.63	20.52
Germany	16.69	410774	2.94	50.03	22.47
Denmark	35.86	414635	3.06	86.97	10.46
France	11.04	363838	2.23	51.97	6.87
Finland	11.39	377131	3.32	66.09	29.04
Ireland	0	436354	1.58	67.62	30.34
Netherlands	23.18	439590	1.98	72.01	15.37
Norway	6.83	583292	1.66	60.97	52.01
Sweden	29.77	424267	3.3	73.13	24.12
UK	19.18	366100	1.63	59.24	36.67
Italy	8.49	327185	1.25	59.37	0
Spain	0	310854	1.24	48.85	0
Portugal	0	254919	1.36	72.66	44.93
Greece	0	238713	0.78	51.64	0

Data sources: national statistical offices (number of students in single universities and total number of students in a country), OECD online database (GDP per capita, total R&D expenditures, public research expenditures within universities).
Year: 2013 or (if not available) 2012.

4.3. Results

Table 5 presents five combinations of conditions that proved to be sufficient for high performance university research. The combinations result from the truth table included in appendix 8 and were selected using a consistency threshold of 0.8, which is commonly accepted in QCA studies (Fiss 2011, Schneider and Wagemann 2012). As proposed by Raging and Fiss (2008), black circles indicate the presence of a condition, while white circles with a cross indicate its absence. As only 16 observations were included in the analysis, table 5 shows all conditions appearing in the complex solution, the solution derived from the observed cases only. Larger circles indicate those conditions also appearing in the intermediate solution, which includes instances of combinations not covered – so-called logical reminders – for which directional expectations have been formulated (see Thiem and Duşa 2012). The parsimonious solution that results from the inclusion of all possible logical reminders would simplify the combination too much and is only mentioned in the comments.

Table 5: Results of the fuzzy-set Qualitative Comparative Analysis

	Configurations related to high research performance				
	1	**2**	**3**	**4**	**5**
Funding agency profiles					
Focus on fellowships	●	●	⊗	⊗	⊗
Focus on bottom-up projects	●	⊗	●	⊗	●
Focus on programs	⊗	⊗	⊗	●	⊗
Focus on thematic research	⨂	⨂	⨂	⨂	⨂
Context factors					
Above-average GDP	●	●	●	●	●
High R&D expenditures	●	⊗	●	●	⊗
Most public R&D in HE	⊗	●	●	⊗	⊗
Competitive HE funding	⊗	⊗	⊗	⊗	●
Cases	AT/BE	NL	CH/DK/ FI/SE	DE	UK
Consistency (inclusiveness)	0.921	0.886	0.893	0.909	0.807
Raw coverage	0.277	0.144	0.416	0.143	0.127
Unique coverage	0.074	0.024	0.238	0.059	0.077
Overall solution consistency (incl.)	0.901				
Overall solution coverage	0.689				

Black circles indicate the presence of a condition, and white circles with a cross indicate its absence. Large circles indicate conditions appearing in the intermediate solution, while small circles indicate additional conditions of the complex solution. The parsimonious solution corresponds to absence of "Focus on thematic research" and presence of "Above-average GDP".

Two conditions are present in all five solutions. First, all combinations feature an above-average GDP, which points to the importance of an overall high level of resources potentially available. Only richer countries seem to have the necessary economic resources – both private and public – to provide a suitable environment for successful university research. Second, in none of the countries identified as best practice the funding agencies included in the analysis focused on thematic research. Too strong an orientation towards thematic funding thus seems to be negatively associated with the research performance of universities.

With respect to the other conditions, the first three solutions display several similarities. They all occur in medium sized countries known for the quality of their higher education and research system, namely, Austria, Belgium, the Netherlands, Switzerland, Denmark, Finland, and Sweden. The three agency profiles identified all represent variations of traditional funding schemes with a focus on fellowships (solution 2), on bottom-up projects (solution 3), or on both (solution 1). Analogous variations can be observed among the context factors. Apart from the high level of GDP per capita, the seven countries are characterized by high R&D expenditures (Austria and Belgium), by most public research being done within universities (The Netherlands) or by both (Switzerland, Denmark, Finland, and Sweden). These findings point to the importance of an overall high level of university funding, which may result from the interplay of different conditions.[38]

Solution number 4 only occurs in Germany, and differs from traditional agency profiles because of its focus on large programs rather than fellowships or projects. This new approach to research funding thus seems a valid option and may prove particularly helpful in cases such as Germany, where a large part of public research takes place outside the university sector. Germany also differs from the other countries in terms of the size of its research systems. Major research programs may be more likely in large countries due to the availability of enough resources, and more relevant because spontaneous cooperation between institutions may occur less frequently due to geographic distance.

Finally, solution number 5 comprises only the UK. As in other countries, its agencies mainly focus on projects and, although thematic grants exist, they do not dominate other

[38] As the example of the Netherlands shows, universities may still profit from a high level of funding even if the share of R&E expenditures to GDP is rather low, as long as they account for most public research.

funding schemes. However, the UK represents the only case with neither a particularly high level of R&D expenditures nor most public research being done within universities. It is also the only country among the selected ones that features a rather high level of competitive funding, with the UK Research Councils accounting for a large share of public R&D funds in universities.

5. Discussion

All cases in the set of countries with high performance research universities featured a funding agency for university research, a result that may point to the necessity of such agencies. However, in the sample at hand, those countries without any funding agencies were also those with GDP per capita below European average and which featured a low share of R&D funding to GDP and/or a low share of public research conducted at universities. In other words, no cases of rich countries without funding agencies were present. The low performance of research within universities may thus be due to the overall lack of financial resources rather than the absence of a funding agency (see also Aghion et al. 2007).

Among the best practice cases identified, all medium sized countries featured rather traditional funding agencies with a focus on fellowships and bottom-up projects. The positive association of such funding schemes to research performance has repeatedly been shown at the level of single researchers (see e.g. Arora and Gambardella 2005, Jacob and Lefgren 2011) and the present study confirms these findings at the country level. The two core tasks of funding agencies, namely, fostering research through grants for investigator-driven projects and promoting the career of young talents through fellowships, are both relevant and none of them can be prioritized. Both are based on peer reviews of bottom-up submissions, focus on academic excellence, and consider previous performance as a selection criteria (Potì and Reale 2007, van Arensbergen et al. 2014). Although young talents usually have less research experience, they may make greater efforts to publish in order to foster their prospective careers.

With respect to the new types of funding schemes, a stronger focus on program funding proved to be a viable alternative to the traditional focus on fellowships and project grants. Program funding also focuses on academic excellence and selects candidates based on peer review and previous research performance. Its specific aims of concentrating funding, promoting networks, and ensuring a critical mass of resources may further optimize the framework conditions for university research (OECD 2014, Orr et al. 2011). With Germany as a clear example of such a system, one may expect program funding to be particularly suited to large countries with a high share of public research conducted outside the university sector. However, because the sample does not include other cases with such a strong focus on program funding, it remains unclear whether these conclusions also apply to smaller countries with a different organization of public research.

QCA not only identifies conditions that need to be present in order to achieve a desired outcome, but also those that need to be absent (see e.g. Raging 1987). For instance, none of the best practice countries focused on thematic research, while several other countries with similar context factors and a focus on thematic research did not perform particularly well in terms of university research.[39] Accordingly, the analysis identified the absence of a focus on thematic funding as a sufficient condition in both the intermediate and parsimonious solutions. This finding reflects the concern that too strong a focus on thematic funding may hinder academic research and negatively affect the academic reputation of universities (Potì and Reale 2007).

As a first policy implication, one should thus stress the importance of traditional funding schemes for the research performance of universities. In best practice countries, funding agencies focus on fellowships, on bottom-up project grants, or on both. While successful countries may also feature a high share of program funding, too strong a focus on thematic grants may affect university research negatively. However, one needs to keep in mind that the present study identified best practices in terms of academic performance. Thematic funding also serves knowledge transfer from academia to society and addresses current societal, economic and political problems (Lepori 2007b). The analysis did not consider such issues and the question whether thematic funding is better suited to address them remains unanswered.

[39] Examples of such countries are France, Ireland, and Norway.

These implications are particularly relevant in the context of the strong increase of funding at the European level.[40] A large part of the European Commission's Framework programs for research and development are allocated through specific thematic calls. The ERC with its focus on excellent, investigator-driven research represents only 17 percent of the total budget of the current eight Framework program Horizon 2020, while the Marie Curie fellowships managed by the REA account for only 8 percent (European Commission 2013). The European Framework programs would thus be clearly classified as a thematic funding agency. If the European Commission aims at taking over traditional funding tasks from national agencies and fostering a common European Research Area with high performance research universities (see e.g. Barré et al. 2013, Luukkonen and Nedeva 2010), the results of this study suggest that a major focus on bottom-up projects, fellowships, and eventually excellence programs may be more appropriate.

Finally, the study also stresses the importance of an adequate level of university funding. All best practice countries displayed an above-average GDP. While this result points to the importance of an overall high level of economic development for university research performance, causality may also work in the opposite direction. Successful research universities may foster economic development by enabling innovations and improving competitiveness of the local industry, providing highly qualified workforce, and attracting high technology and research-based enterprises (see e.g. Rosenberg and Nelson 1994). Nevertheless, the importance of sufficient university funding is also emphasized by the presence of a high share of R&D expenditures, a high share of university research spending, or both in almost all best practice countries.[41]

The United Kingdom represents the only exception among best practice countries in terms of university funding. The analysis suggests that it may compensate the rather low share of R&D expenditures and university research spending by a high share of research funds allocated through agencies and thus by a particularly competitive funding environment. However, empirical evidence is too small to confirm that a high degree of

[40] While the annual allocations under the first European framework program amounted to 593 million Euro in 1984, they increased to around 10 billion Euro in 2013 (State Secretariat for Education, Research and Innovation 2013).

[41] An above-average GDP and a high share of R&D or university research expenditures are important factors, but not sufficient for highly successful research universities. For instance, France, Ireland, and Norway dispose of similar resources to the best practice cases, but do not fall into the set of countries with high performance research universities.

competition fosters research performance. Moreover, there might be other reasons for the success of UK research universities apart from the funding system. First, international rankings are said to be biased towards universities in English-speaking countries, making it easier for the UK to achieve better positions (Hazelkorn 2015).[42] Second, the UK features a small number of universities with a long tradition of excellence and a worldwide reputation. These universities are among the few institutions in Europe that dispose of considerable endowments and are thus less dependent on the design of the national funding system.[43]

6. Conclusions

The present study aimed at providing a better understanding of public agencies in charge of funding university research. It represents a first attempt to study these agencies empirically from a broad international comparative perspective. In a first step, comparable data across several Western European countries were collected in order to provide an overview of the broad characteristics of existing funding agencies. By means of cluster analysis, four types of funding agencies were identified based on their funding profiles. In a second step, a fuzzy-set QCA analysis helped to identify best practices at country level. While best practice countries featured either a focus on traditional funding schemes, namely, fellowships and bottom-up projects, or large programs, a focus on thematic grants proved to be associated to lower performance of research universities.

The analysis confirmed that, although great differences across countries exist, common patterns can be found, and comparative investigations of funding approaches at national level are possible. Specifically, QCA allows for multiple causal combinations of conditions to explain an outcome of interest and thus accounts for the different societal, economic and political context factors in which funding agencies and research universities act. The approach thus led to differentiated findings that can be translated into relevant policy implications. Apart from the importance of traditional approaches to research funding and

[42] To measure research performance, most international university rankings, such as the ARWU, employ data from Thomson Reuter's Web of Science database, which mainly lists English-speaking publications.

[43] As shown by Michael (2005), endowment is highly correlated to research performance, as it gives universities additional resources that they can freely allocate internally and strengthens them in the competition for third party funds.

the problems that too strong a focus on thematic grants may cause, the findings confirm that a high level of university funding is essential for an internationally highly reputed university research system.

Although the study provided remarkable empirical results, it was also subject to several important limitations that call for further research. First, the extraordinary complexity and diversity of funding systems could only partly be addressed. Several simplifications had to be accepted and other factors that possibly affect research performance were not included in the analysis. For example, an analysis of the internal organization of funding agencies, the composition of their boards, and their decision processes was far beyond the scope of this study. Similarly, several context factors at country level, such as possible effects of other funding sources, were not included due to the lack of internationally comparable data. Future studies may thus examine specific organizational features of funding agencies, and focus more on the context in which they act, investigating their relationship to the state and to other external funding sources for university research.

Second, several data issues hindered the analysis and finding viable solutions was very laborious. For instance, it proved difficult to collect internationally comparable figures on funding agencies due to different definitions of the data at hand and varying reporting practices across countries. Many funding agencies did not collect some of the figures requested, or did not provide access to all information. Given that these agencies manage very large amounts of research funding and that a growing interest in empirical, comparative studies exists, the introduction of common data collection and data management practices is strongly recommended. The full availability of comparable figures would allow for more detailed analyses and meaningful conclusions.

Finally, the empirical lack of specific combinations of conditions represents a common problem in QCA analyses, especially if the number of cases is small. Some of the association patterns identified could not be further investigated because only one country displayed the corresponding combination and no counterfactual cases were available. One possible way to address this problem would be to widen the scope of the study including further funding agencies from other geographic regions and thus increasing the diversity of the sample.

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Appendix

Appendix 1

Indicators for expenditures and personnel of European academic research funding agencies (2013)

Country	Agency	Total expenses	Growth 2009-2013	Administr. costs	As % of tot. expenses	FTE	Funding per FTE
Austria	FWF	231.2	4.4	9.3	4.0	84.01	2.6
Belgium	FNRS	168.1	-0.8	8.8	5.2	58.8*	2.7*
Belgium	FWO	226.4	7.2	7.2	3.2	50	4.4
Denmark	DNRF	58.9	40.3	2.1	3.6	9*	6.3*
Denmark	DFF	163.8*	-3.0*	3.1*	1.9*	39	4.1
France	ANR	596.0	-31.4	33.1	5.6	245	2.6
Germany	DFG	2692.1	10.1	61.2	2.3	654.75	4.0
EU	REA	1439.8	106.7	45.9	3.2	545	2.6
EU	ERC	1762.5	89.3	40.1	2.3	379	4.5
Finland	AKA	338.6	18.7	14.8	4.4	135.3	2.4
Ireland	SFI	161.7	-13.7	9.2	5.7	47	3.2
Ireland	ICR	36.5*					
Netherlands	NWO	735.2	10.0	53.5	7.3	440	1.5
Norway	RCN	933.2	13.1	76.0	8.1	448	1.9
Portugal	FTC	436.0	-13.6	12.6	2.9	256*	1.7
Sweden	SRC	698.8	55.9	43.3	6.2	169	3.9
Sweden	SSF	133.2	113.4	5.6	4.2	14.6	8.7
Switzerland	SNSF	780.3	57.4	32.7	4.2	193	3.9
UK	AHRC	129.1	-9.6	8.6	6.7	82	1.5
UK	BBSRC	610.5	-4.6	21.9	3.6	247.6	2.4
UK	EPSRC	1020.4	-7.9	37.6	3.7	225	4.4
UK	ESRC	262.5	-2.8	12.8	4.9	138	1.8
UK	MRC	1026.6	-3.0	305.4	29.7	4101	0.2
UK	NERC	517.4	-1.7	241.3	46.6	2328	0.1
UK	STFC	615.0	-23.4	266.6	43.4	1723	0.2

* Estimate or approximation.
Total expenses are in million Euro. Total expenses include both funding allocations and administrative expenses. Funding per full-time equivalent (FTE) includes only funding allocations. Growth 2009-2013 refers to real growth (2013 prices).

Appendix 2

Indicators for submissions and grants of European academic research funding agencies (2013)

Country	Agency	Sub-missions	Projects granted	Money granted	Acceptance rate 2013	2009	Money per project	Growth 2009-2013
Austria	FWF	2386	632	202.6	26	35	320.6	19.7
Belgium	FNRS	566	203		36			
Belgium	FWO	2967	785		26	35		
Denmark	DNRF	200*	17	101.1	9*	5*	5944.6	-13.8
Denmark	DFF	2347	457	160.7	19	18	351.5	23.1
France	ANR	7209	1068	588.6	15	21	551.1	-16.9
Germany	DFG	11322	3521	685.6	31	47	194.7	-13.4
EU	REA	14068	2044	1741.1	15	28	851.8	55.5
EU	ERC	9928	981	1800.0	10	13	1834.9	2.2
Finland	AKA	3477	1030	334.9	30	38	325.1	62.5
Ireland	SFI	2013	307	297.2	15	17	968.1	116.9
Ireland	ICR	1449	287	22.3	20		77.7	
Netherlands	NWO	5268	1318		25	30		
Norway	RCN	5474	1049	769.2	19	21	733.3	28.6
Sweden	SRC	6800	935	396.2	14	15	423.7	38.8
Sweden	SSF	500*	100*	55.7	20*	20*	557*	110.6*
Switzerland	SNSF	5360	2769	664.6	52	58	240.0	31.1
UK	AHRC	978	333	85.3	34	17	256.3	54.9
UK	BBSRC	1865	511	307.2	27	22	601.2	9.7
UK	EPSRC	1918	620	430.7	32	41	694.7	15.6
UK	ESRC	334	82	40.8	25	16	497.7	122.1
UK	MRC	1360	306	316.8	23	19	1035.3	24.8
UK	NERC	937	172	61.6	18	19	358.4	19.1

* Estimate, average, or approximation.
Money granted and money per project are in million Euro. Empty cells indicate missing information. The data is only partly comparable as not all agencies report the same type of submissions and grants. The FTC (Portugal) and the STFC (UK) are excluded from the table, as the corresponding figures could not be gathered.

Appendix 3

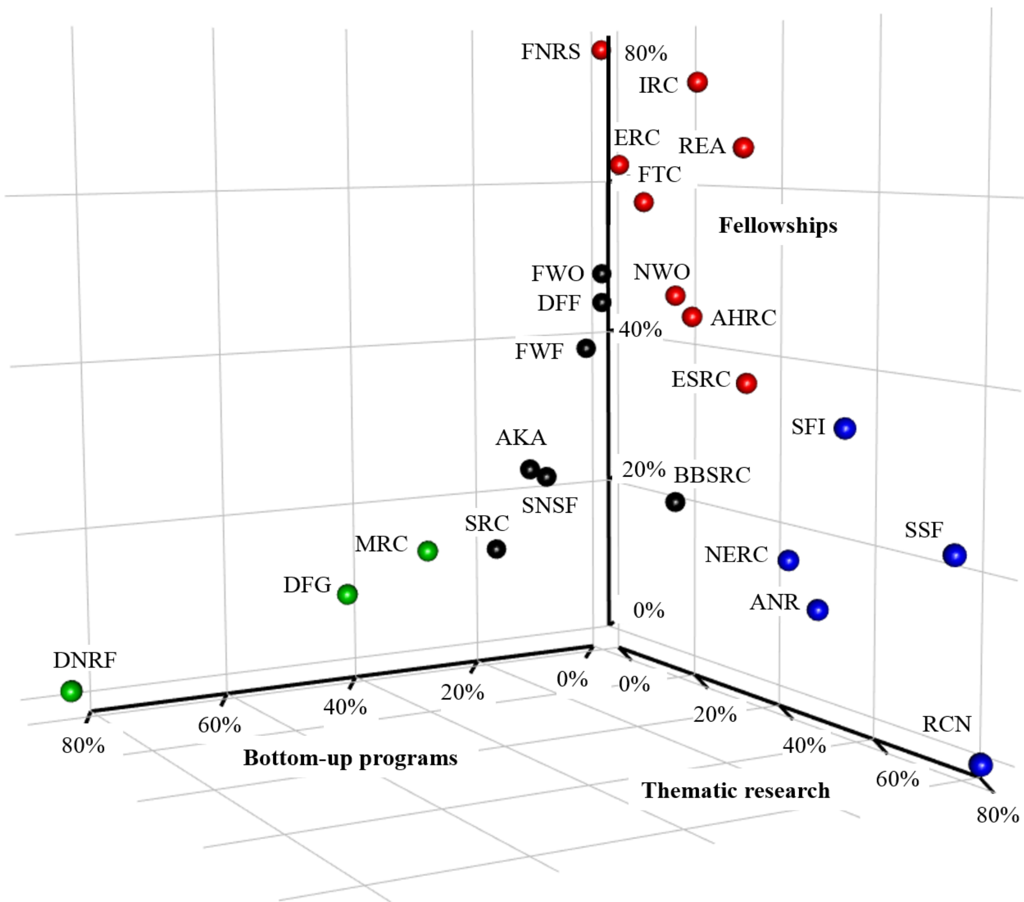
Categories of funding instruments of academic research funding agencies (for the Year 2013)

Country	Agency	Fellowships		Projects		Programs		Thematic		Other		Total
		Euro	%	Euro	%	Euro	%	Euro	%	Euro	%	Euro
Austria	FWF	77.5	35.2	106.9	48.5	9.7	4.4	6.6	3.0	19.5	8.9	**220.2**
Belgium	FNRS	116.8	72.6	34.5	21.4	0.0	0.0	0.0	0.0	9.6	6.0	**160.9**
Belgium	FWO	102.9	47.0	111.6	51.0	0.0	0.0	0.0	0.0	4.3	2.0	**218.8**
Denmark	DNRF	1.8	3.2	0.0	0.0	49.4	87.0	5.6	9.8	0.0	0.0	**56.7**
Denmark	DFF	68.8	42.8	86.9	54.1	0.0	0.0	0.0	0.0	5.0	3.1	**160.7**
France	ANR	49.4	11.5	157.7	36.6	0.0	0.0	223.4	51.9	0.0	0.0	**430.5**
Germany	DFG	263.6	10.0	749.1	28.4	1131.7	43.0	244.2	9.3	244.6	9.3	**2633.2**
EU	REA	902.6	64.7	0.0	0.0	0.0	0.0	491.4	35.2	0.0	0.0	**1394.0**
EU	ERC	612.0	62.4	289.0	29.5	13.0	1.3	67.0	6.8	0.0	0.0	**981.0**
Finland	AKA	66.6	19.9	135.9	40.7	48.7	14.6	24.4	7.3	58.3	17.5	**333.9**
Ireland	SFI	45.3	29.7	13.0	11.5	0.0	0.0	77.9	51.1	16.4	10.8	**152.6**
Ireland	ICR*	24.9	72.7	1.0	2.9	0.0	0.0	8.4	24.5	0.0	0.0	**34.3**
Netherlands	NWO*	159.0	27.8	119.0	20.8	0.0	0.0	66.0	11.5	229.0	40.0	**573.0**
Norway	RCN	0.0	0.0	111.7	11.8	0.0	0.0	558.5	59.1	275.6	29.1	**945.8**
Portugal	FTC	192.9	45.6	104.3	24.6	0.0	0.0	37.4	8.8	88.8	21.0	**423.4**
Sweden	SRC	57.3	8.7	312.6	47.7	82.4	12.6	0.0	0.0	203.3	31.0	**655.6**
Sweden	SSF	13.2	21.7	0.0	0.0	0.0	0.0	47.5	77.9	0.2	0.3	**60.9**
Switzerland	SNSF	134.7	21.5	313.2	50.0	86.6	13.8	50.5	8.1	41.1	6.6	**626.2**
UK	AHRC	49.7	41.3	37.3	31.0	0.0	0.0	26.4	21.9	6.5	5.4	**119.9**
UK	BBSRC*	61.6	10.8	368.5	64.6	0.0	0.0	0.0	0.0	140.7	24.7	**570.8**
UK	EPSRC	266.4	27.1			0.0	0.0			19.5	1.5	**1050.1**
UK	ESRC	62.1	24.9	46.4	18.6	0.0	0.0	61.2	24.5	79.8	32.0	**249.6**
UK	MRC*	82.3	8.3	176.7	17.7	189.3	19.0	68.9	6.9	478.3	48.0	**995.4**
UK	NERC	33.9	7.0	78.6	16.1	0.0	0.0	94.2	19.3	280.4	57.6	**487.1**
UK	STFC	26.4	3.7	120.8	17.0	0.0	0.0	0.0	0.0	562.6	79.3	**709.8**

* Includes estimations.
The amount of funding is measured in million Euro. The EPSC could provide neither figures nor an estimate of the share of bottom-up grants to total grants. The 686.7 million Euro allocated through research grants (correspond to 69.9 percent of total funding) are thus not reported in the table.

Appendix 4

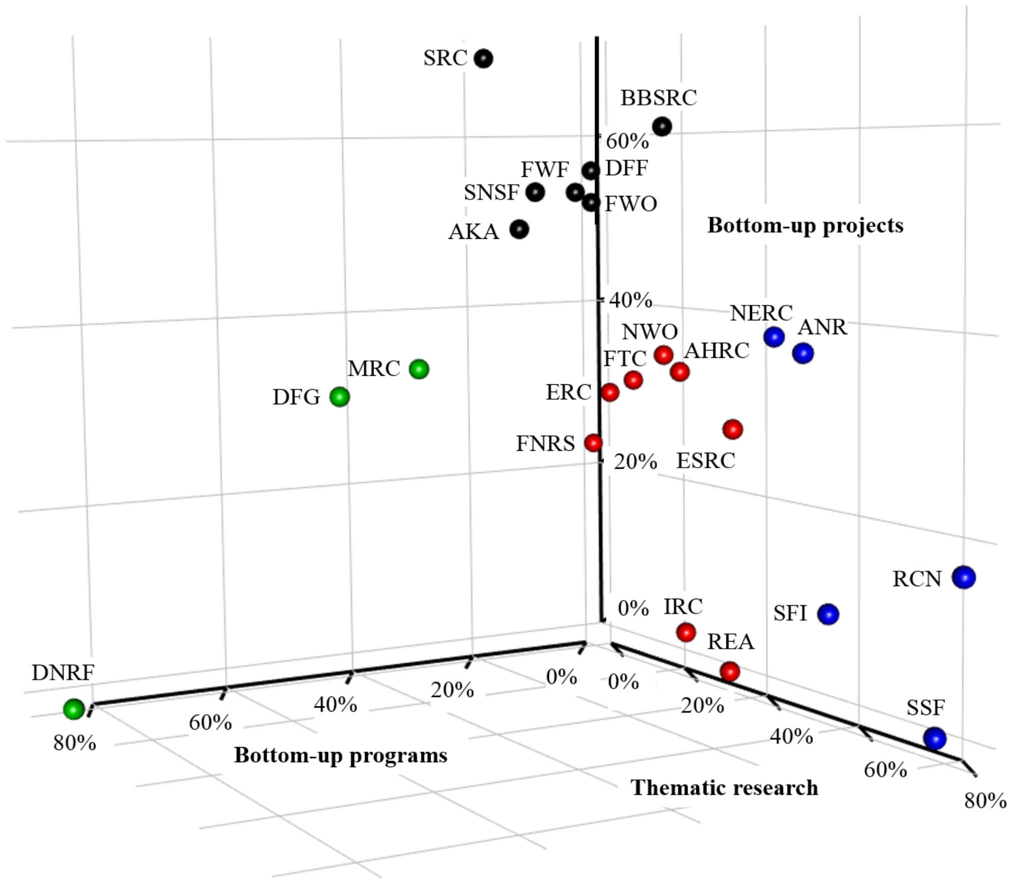
Relative funding for bottom-up programs, thematic research, and fellowships in the four clusters identified



- First cluster: high share of thematic research
- Second cluster: high share of bottom-up programs
- Third cluster: high share of bottom-up projects
- Fourth cluster: high share of fellowships

Appendix 5

Relative funding for bottom-up programs, thematic research, and bottom-up projects in the four clusters identified



- First cluster: high share of thematic research
- Second cluster: high share of bottom-up programs
- Third cluster: high share of bottom-up projects
- Fourth cluster: high share of fellowships

Appendix 6

Short description of QCA

In a first step, QCA creates a so-called truth table that displays all possible combinations of conditions and outcomes. The full truth table has thus 2^k rows, with k being the number of conditions used (Fiss 2011). All cases included in the analysis are then sorted into the rows of the truth table according to their membership scores in each set. Usually, not all possible combinations can be observed empirically and many rows remain wide.

In a second step, QCA selects the rows that display a minimum number of cases, which has been defined in advance. In the present study, the minimum number of cases is set at 1, as the analysis only covers 16 cases. Moreover, these combinations need to reach a specific consistency level, with the minimum recommended threshold being at 0.75 (see e.g. Raging 2008). The consistency level measures the degree to which the empirical cases match the combination they were assigned to. In fuzzy-set QCA, the consistency of sufficient conditions is calculated as follows (Schneider and Wagemann 2012):

$$Consistency_{Sufficient\ conditions\ (X_i \leq Y_i)} = \frac{\sum_{i=1}^{I} \min(X_i, Y_i)}{\sum_{i=1}^{I} X_i}$$

where X_i and Y_i are the membership scores of each case in the sets representing the conditions and the outcome of interest. A related measure is coverage, which indicates how much of the outcome is covered by a specific condition. It can be computed using the following formula (Schneider and Wagemann 2012):

$$Coverage_{Sufficient\ conditions\ (X_i \leq Y_i)} = \frac{\sum_{i=1}^{I} \min(X_i, Y_i)}{\sum_{i=1}^{I} Y_i}$$

In a third step, QCA applies Boolean algebra to reduce the selected combinations and to identify the conditions that are sufficient (or necessary) for an outcome to occur.

Appendix 7

Set-memberships in different conditions included in QCA after calibration

Country	Fellow.	Proj.	Progr.	Them.	GDP	R&D	HE to R&D	Agency to HE	OUT
Austria	0.55	0.76	0.10	0.07	0.77	0.91	0.21	0.04	0.64
Belgium	0.86	0.57	0.00	0.00	0.64	0.64	0.36	0.48	0.77
Switzerland	0.33	0.76	0.30	0.17	1.00	0.98	1.00	0.26	1.00
Germany	0.16	0.45	0.95	0.20	0.70	0.97	0.00	0.31	0.45
Denmark	0.47	0.58	0.46	0.05	0.72	1.00	1.00	0.01	0.98
France	0.16	0.52	0.00	1.00	0.55	0.62	0.07	0.00	0.30
Finland	0.35	0.70	0.35	0.18	0.59	1.00	0.54	0.48	0.31
Ireland	0.59	0.12	0.00	1.00	0.79	0.29	0.59	0.51	0.00
Netherlands	0.66	0.49	0.00	0.38	0.80	0.49	0.73	0.13	0.63
Norway	0.00	0.24	0.00	1.00	1.00	0.33	0.37	1.00	0.19
Sweden	0.20	0.87	0.32	0.19	0.75	1.00	0.77	0.35	0.81
UK	0.33	0.80	0.15	0.26	0.55	0.32	0.31	1.00	0.52
Italy	0.00	0.00	0.00	0.00	0.42	0.13	0.31	0.00	0.23
Spain	0.00	0.00	0.00	0.00	0.37	0.12	0.00	0.00	0.00
Portugal	0.82	0.45	0.00	0.22	0.18	0.18	0.76	0.87	0.00
Greece	0.00	0.00	0.00	0.00	0.13	0.00	0.05	0.00	0.00

OUT indicates the performance measure used to identify best practices, i.e. the relative number of students at internationally renowned universities.

Appendix 8

Truth table resulting from the QCA analysis (only covered cases)

Fellow.	Proj.	Progr.	Them.	GDP	R&D	HE to R&D	Agency to HE	OUT	n	Consist.	PRI	Cases
1	1	0	0	1	1	0	0	1	2	0.921	0.749	AT, BE
0	0	1	0	1	1	0	0	1	1	0.909	0.000	DE
0	1	0	0	1	1	1	0	1	4	0.893	0.827	CH, DK, FI, SE
1	0	0	0	1	0	1	0	1	1	0.886	0.693	NL
0	1	0	0	1	0	0	1	1	1	0.807	0.179	UK
0	1	0	1	1	1	0	0	0	1	0.692	0.000	FR
1	0	0	0	0	0	1	1	0	1	0.569	0.183	PT
1	0	0	1	1	0	1	1	0	1	0.364	0.028	IE
0	0	0	1	1	0	0	1	0	1	0.363	0.000	NO
0	0	0	0	0	0	0	0	0	3	0.262	0.000	IT, ES, GR

OUT indicates the performance measure used to identify best practices, i.e. the relative number of students at internationally renowned universities.

Curriculum vitae

Personal information

Name:	Stefano Nigsch
Date of Birth:	March 10, 1982
Nationality:	Swiss

Education

09/2011 – 04/2016	Ph.D. studies in Business Administration University of Zurich
10/2001 – 10/2008	Licentiate (corresponds to M.A.) in Political Science University of Zurich
09/2006 – 07/2007	Academic Year at the Lobachevsky State University in Nizhni Novgorod, Russia

Professional experience

01/2016 – today	Assistant of the President University of Basel
08/2012 – 12/2015	Scientific associate at the Office of the Vice President for Law and Economics, University of Zurich
07/2011 – 12/2015	Research assistant at the Department of Business Administration University of Zurich
04/2009 – 07/2012	Scientific advisor at the Secretariat of the Swiss Science and Innovation Council, Bern